





THE  
Philosophical Grammar;

Being a VIEW of the  
PRESENT STATE  
OF  
EXPERIMENTED PHYSIOLOGY,  
OR,  
NATURAL PHILOSOPHY.  
IN FOUR PARTS.

PART I. SOMATOLOGY, treateth of the universal Nature and Properties of Matter, or Substance, and the specific Qualities of natural Bodies.

PART II. COSMOLOGY, exhibiteth a general View of the Universe, and its great constituent Parts; the Sun, Moon, Planets, Comets, fixed Stars, &c.

PART III. AEROLOGY, compriseth the Philosophy of the Atmosphere, shewing the wonderful Nature and Properties of the Air, Wind, Meteors, and other Phænomena therein.

PART IV. GEOLOGY, containeth a Philosophical View of the terraqueous Globe, in all its Parts and Productions; as Minerals, Metals, Stones, &c. The Laws of Fluids; the Sea, its Tides, &c. Of Rivers, Springs, &c. Of Vegetation, and the Nature of Plants, Trees, &c. Of the Parts of animal Bodies; and a Survey of the Nature of Beasts, Birds, Fishes, Insects, Reptiles, Shell-Animals, &c.

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The SEVENTH EDITION, with *Alterations, Corrections*, and  
very large *Additions*, by Way of *Notes*.

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BY BENJ. MARTIN, Φιλότεχνος. *K*

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*The Works of the Lord are great, sought out of all them that have Pleasure therein,*  
Psalm cxi. 2.

*Philosophia mater omnium bonarum artium, nihil est aliud, nisi, ut Plato ait,*  
*donum et inventum Deorum, Cicero, 1. Tusc.*

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MDCCLXIX.

Philosophical Transactions

For the Year 1785

Part I

Containing

Experimental Philosophy

and

Natural History

As far as they relate to the

Human Mind

By

JOHN DE LAUNCELOT

OF THE

ROYAL SOCIETY

AND

OF THE

ARTS

AND

OF THE

ROYAL SOCIETY

AND

OF THE

ARTS

AND

OF THE





T H E  
P R E F A C E.

**T**HE favourable Reception the former Editions have met with, inclines me to hope that this seventh Edition will find farther Encouragement from the Public; especially when it is known what great Improvements are made through the whole Work since the first Edition of this Book, both by the Advice and Remarks of many learned and judicious Persons, (which I here gratefully acknowledge) and my own Observations. All this has produced considerable Alterations, Corrections,

A 2



## P R E F A C E.

*tions, and Additions ; for many new and curious Subjects, and ten new Plates, are added : And the most approved Authors, who have treated more largely of these Things, than can be expected in this small Volume, are referred to. I shall add no more, but that this Book is designed for the Instruction and Entertainment of the Youth of both Sexes : And that it may so delight and allure them, as to engage them to pursue true Knowledge to a greater Perfection, is the sincere Desire of*

*Their humble Servant,*

BENJAMIN MARTIN.

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THE



T H E

# *Philosophical Grammar.*

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## C H A P. I.

*Of the Science of Philosophy in general; of Natural Philosophy in particular; its Parts and Subjects, and various Uses in Life.*

A. **W**HAT is the genuine Meaning of the Word *Philosophy*?

B. By Philosophy, you are to understand the Science or Knowledge of the Nature, Causes, Properties, and Effects of all created Beings, so far as they are capable of being known by Reason, discovered by Art, or any Ways adapted to the human Comprehension\*.

\* The Word PHILOSOPHY among the Ancients was used in a various Sense; for, (1.) It sometimes was taken for *Universal Knowledge*, viz. of all Things, *Human* and *Divine*. (2.) In a stricter Notion, for the *Contemplation of Nature only*; and in this Sense a Philosopher was called by *Plato*, φίλος τῆς φύσεως, A *Friend*, or *Lover of Nature*. (3.) Sometimes for *Ethics*, or the Doctrine of Manners; which we call *Moral Philosophy*. (4.) It also included the *Mathematical Arts and Discipline*, especially *Arithmetic* and *Geometry*. (5.) The Science τῆς οὐλως οὐλος, of *Existence* or *Being* in the *Abstract*, called *Metaphysics*. (6.) For the Knowledge τῆ πρώτης καλῆς, of the *Prime* or *Chief Good*, i. e. *God*; and this was their *prima Philosophia*, or *Theology*. (7.) It was sometimes applied to *Logic*, or *Dialectics*, which gave Rules for Reasoning about the Nature of Things.—But on the Whole, the Knowledge of *God*, *Nature*, and *Arts*, was so very imperfect and scanty, that Philosophy seems but *dawning* in the Works of its greatest Professors among them.

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*A.* Please to be a little more particular in your Definitions, or I cannot so easily (as I would) apprehend you: What do you mean by the *Nature of Things*?

*B.* By the *Nature* of any Being, or Thing, is meant that peculiar State, or Condition, whereby it is differenced in its Kind from all other Beings whatsoever: Thus it is the Nature of God to be perfect; of Man to be sociable; of Fire to be hot; of Ice to be cold, &c.

*A.* In like Manner explain what you mean by the *Causes of Things*, that I may the better apprehend you on these Philosophical Subjects.

*B.* By *Natural Causes* are to be understood the Means by which Things come at first to have their Being or Existence: Thus God is the Cause of all created Beings, because from him they first received their Being; and hence God is called by way of Preheminence the *first* and *primary Cause* of all Things.

*A.* I have heard, and also read of *secondary Causes*; pray, what is the Reason of this Distinction?

*B.* I'll endeavour to inform you. *Secondary Causes* are those which produce their Effects according to the Direction and Influence of some established and original Laws and Rules, implanted in their Natures at their first Creation by God, the *primary Cause*; of all other Causes he is the original Cause; and consequently they, with Regard to the *first Cause*, can be only properly termed *secondary Causes*:

*Causes*: So the Sun causeth Vapours; and Vapours cause Clouds; and Clouds condensed cause Rain; Rain causeth Springs, Rivers, Vegetation, &c. but yet they all act in a secondary Manner, under the original Influence of the first Cause, as aforesaid\*.

*A.* Please next to define what you call the *Properties* of Bodies.

*B.* By Bodies, I suppose, you mean the several Kinds of Beings in general, as they appear to our Sight; and, in this common Sense of the Word, the *Properties* of Things are those Qualities and Operations peculiar to themselves, and which distinguish them from all other Kinds of Beings: Thus it is the Property of Man to laugh, and reason; of Glass to be transparent; of Air and Wind to be invisible; of Space to be infinite; of God to do Good, &c.

*A.* The Knowledge of Effects you mentioned as a Part of Philosophy; what am I to understand thereby?

*B.* This: That an Effect is whatever is produced or brought to pass by the Action or Operation of any natural Cause: Thus Vapours are the Effect of the Sun's Attraction; Ice is the Effect of a cold Air; Visibility the

\* The Doctrine of *Secondary* and *Final Causes*, is of the last Importance in true Philosophy; since the former are the *Means by which*, and the latter, the *Ends for which*, all Things receive their Being from the Primary Efficient Cause, which is God alone.



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Effect of Light ; and Purging and Vomiting the Effects of divers Herbs and Medicines.

*A.* Having given this general Account of Philosophy, I should be glad if you'd oblige me with a more particular one ; pray, how many Sorts of Philosophy are there ?

*B.* Philosophy is divided generally into Moral and Natural.

*A.* What do you call Moral Philosophy ?

*B.* This is properly called *Ethics*, from the Greek Word *ἠθικῶς*, and *Morality*, from the Latin Word *Mos*, plural *Mores*, both signifying *Manners* or *Behaviour*.

*A.* Pray, what is the Business of Moral Philosophy ?

*B.* To give Rules and Laws for the Behaviour, Manners, and Conduct of Man, as Man, or as a rational Creature.

*A.* Please to tell me the End or Design thereof.

*B.* The great End and Design of Morality is to make Mankind acquainted with the Means and Methods of being happy, or to obtain the greatest Felicity in this Life.

*A.* What do you properly call Natural Philosophy ?

*B.* This hath two proper Appellations ; one is *Physic*, from the Greek *φυσικῶς*, *Nature*, or *φυσικὴν*, *Natural* ; and so it imports to us the Science or Knowledge of Nature, or natural Bodies.

*A.* But you say it hath another Name ; what is that ?

*The Differ. of moral and natural Philosophy. 7*

B. *Physiology*; so called of φύσις, *Nature*, and λόγος, a *Discourse*; and by this is implied a Discourse of Nature, and natural Bodies; and such is the ensuing Book \*.

A. Since the Word *Philosophy*, then, is general; what is implied by it?

B. The Word *Philosophy* is compounded of the two Greek Words φιλία, *Love*, and σοφία, *Wisdom*, or *Knowledge*; and thus it implies the Love of Wisdom, or the Study of Knowledge or Learning in general, as aforesaid †.

A. How came the Word *Philosophy* first in Use?

B. *Pythagoras*, a learned Greek Philosopher of Samos, from his great Modesty, esteemed the Appellation σοφός, a *wise Man*, too arrogant, (though the general Character of a learned Man before his Time) and therefore he was content to call himself φίλος, a *Lover*, σοφίας, of *Wisdom*: And since him the Science has been called *Philosophy*, i. e. *Love of Wisdom*; and those who study it, *Philosophers*.

\* The Greek Word φύσις, and the Latin *Natura*, (whence the English Word *Nature*) are both derived from Verbs, viz. φύω and *Nascor*, which signify to *make*, *produce*, *beget*, or *give Being* to any Thing. Thus *Nature*, properly speaking, is the *General Birth* of all Things.

† The Word *Philosophy*, though literally Greek, yet is of an Hebrew Derivation; for φιλία seems to be from הפל, to *separate*, set apart, select; which is the Act of *Love* in a most eminent Degree: And σοφία is evidently from הפז, to *observe*, *explore*, *view*, and *contemplate* Things; which is the proper Business of a *Naturalist*. And thus from הפז came the Greek σοφοί, or *Contemplative Wise Men*.—Yet notwithstanding this, such poor *Philosophers* were the *Hebrews*, that their Language affords not one Word for *Nature* or *Philosophy*.

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*A.* Very good ; but say, what is the proper Subject of Natural Philosophy ?

*B.* Substance or Matter, under all the various Forms and Figures we behold it, which we call natural Bodies, with all their Properties and Affections.

*A.* What is the Design of Natural Philosophy ?

*B.* To improve human Knowledge, to make us better acquainted with Nature, to give us a rational Sense of Things, by discovering the Reason of the various and different Affections, Qualities, and Effects of Objects, which offer themselves to our Senses, so far as is possible.

*A.* What are the more principal Uses of Philosophy in the Affairs of human Life ?

*B.* They are almost innumerable ; for hereby Men are distinguished from Brutes, who indeed behold the various Phases of Nature, but can tell the Reason or Cause of none. By this Art, the *Physician* acquires the Knowledge of the Virtue and Effects of Plants and Herbs ; the *Chymist* hereby obtains the Method of analyzing and dissolving Metals, Minerals, Plants, animal Substances, &c. and reducing them to their first Elements ; the *Apothecary* hence understands the Reason of the various Compositions of Simples for the making his Medicines ; the *Astronomer* hence learns the Frame and Constitution of the Heavens, and the Magnitude, Distance, and Phases of all the heavenly Bodies ; the  
*Husband-*



*The Parts and Subdivisions of Physiology.* 9

*Husbandman* also may know, from the Rules of this Science, the most advantageous Methods of cultivating and manuring his Land; the *Navigator*, from hence, borrows the Theory of his Art; and, in short, there is no State, Art, or Capacity, in Life, which does not directly, or indirectly, receive Advantage and Benefit therefrom.

C H A P. II.

*Of the Parts and Subdivisions of*  
P H Y S I O L O G Y.

A. **H**OW many are the Parts of this Science of natural *Physiology*?

B. It may properly be divided into four general Parts.

A. Which are they?

B. These following, *viz.*

I. *Somatology*, which treateth of the common Nature, Properties, and Qualities of *Matter*, and its various Combinations in *natural Bodies*.

II. *Cosmology*, or *Uranology*, which treats of the Nature, Constitution, and component Parts of the *Universe* in general, and particularly of our *solar System*.

III. *Ærology*, which treats of the Nature of the *Atmosphere*, or Region of *Air*,  
and

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and all the *Phænomena* thereto belonging\*.

IV. *Geology*, which treats of the Nature, Make, Parts, and Productions of the *Globe of Earth* on which we live.

*A.* I suppose each of those general Parts receive a Subdivision, do they not?

*B.* Yes, into several other Branches.

*A.* What are the Subdivisions of the first general Part, *Somatology*?

*B.* *Somatology*, as it considers the common and special Properties of natural Bodies, is divided, with respect to them, in the Manner I shall by and by name to you, when we discourse of that Part.

*A.* What are the particular Branches of the second general Part?

*B.* *Cosmology*, or more properly *Uranology*, comprehends the following Branches, *viz.*

1. *Heliography*, which treats of the *Sun*.
2. *Selenography*, which treats of the *Moon*.
3. *Planetography*, which treats of the *Planets*.
4. *Cometography*, which treats of the *Comets*.
5. *Astrography*, which treats of the fixed *Stars*.

\* The Word *Phænomenon* being of most frequent Use, it is proper the Reader should be acquainted, that it is derived from the Greek Verb φαίνω, to appear; whence *Phænomenon* signifies an *Appearance*, and plurally, *Phænomena*, the *Appearances* of Things.

*A.* How

*The Parts and Subdivisions of Physiology.* 11

A. How is the third Part subdivided?

B. *Ærology* I divide as follows, *viz.* into,

1. *Ærography*, which treats of the *Atmosphere*, or Body of *Air*.

2. *Anemography*, which treats of the *Winds*.

3. *Meteorography*, which treats of the *Meteors*.

4. *Plantasmatography*, which treats of the *celestial Appearances*, or such *Phænomena*, as exist only in Vision, and not corporally.

A. How do you subdivide the last general Part?

B. *Geology* is most naturally divided into the following subordinate Branches, *viz.*

1. *Geography*, which treats of the *Earth*, or *Land*.

2. *Hydrography*, which treats of *Water*.

3. *Phytography*, which treats of *Plants* and *Vegetables*.

4. *Zoography*, which treats of *Animals* of all Kinds.

And thus you have a concise View of the several Parts or Subjects of our ensuing *Colloquies*.

A. Sir, nothing will so much delight me, as Reflections on such Topics as these; I always love to hear People talk of the Wonders of Nature, and being now directly engaged in a Conversation of that Kind, my Desires are excited almost beyond Expression.

B. I'll



*B.* I'll do my Endeavour to satisfy you if possible, and am very glad to find you hunger and thirst after useful Knowledge; while others vainly spend their precious and irrevocable Time in idle and profane Amusements, you have the Happiness of superior Sense to dictate to you the more noble, manlike, and virtuous Methods of improving your Time; which will yield you not only Abundance of Delight, and rational Pleasure, but at the same Time make you wise and happy: To this End, I shall communicate to you whatever I have found in the Writings of the great *Sages* and *Virtuosoës* of the last and present improving and inquisitive Age, and will endeavour to make all Things plain and easy, as I go along, by familiar Instances, and plain demonstrative Figures and Schemes.

## C H A P. III.

*Of* AXIOMS *relating to* PHYSICS; *of*  
*the* RULES *of* PHILOSOPHIZING.

*A.* **A**RE there not some fundamental *Principles*, or *Axioms*, on which this Science depends?

*B.* Yes, most certainly; the chiefest of which I shall here lay down.

*A.* What do you make the first *Axiom*?

*B.* *Axiom* I. *Nothing bath no Properties.*

*A.* Please

A. Please to exemplify this *Axiom*.

B. I will : But first understand, that by *No-thing*, is meant a State of *Non-Existence*, or *Not-Being* ; and therefore to say nothing is hot, is cold, hath Parts, is great or small, &c. would be absurd.

A. What is the second *Axiom* ?

B. *Axiom II. Somewhat doth exist.*

A. That's somewhat merry, *Sir* ; I believe No-body will deny that to be an *Axiom*, indeed.

B. You may think of it as you please, but I assure you I have met with those who have had recourse to *Logic*, to prove their own Existence\*.

A. Pray, let me know your third *Axiom*.

B. *Axiom III. There is no Medium between Something and Nothing, Existence and Non-Existence.*

A. This is most certainly true, and to suppose the contrary were absurd ; pray, let me know your fourth *Axiom*.

B. *Axiom IV. That which doth exist, and is independent on any other created Being for its Existence, is properly the Essence or Substance of the Thing existing.* The Truth of this, though extremely evident to those who have been used to a philosophical Way of Thinking,

\* Witness the trite *Enthymem* of the Schools, *Ego cogito, ergo sum*, i. e. I think, therefore, I am, or do exist. The *Sceptics*, it is well known, were absurd enough to deny the Certainty of any Thing, and, consequently, of their own Existence.

will,

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will, perhaps, appear more clear to you farther on.

*A.* Let me hear your next *Axiom*.

*B.* *Axiom V. No Substance, or Essence, can be produced out of Nothing; or it is impossible Nothing should be made Something* \*.

*A.* This indeed is very true; for if Nothing could be made Something, it would then have some Property, which is contrary to your first *Axiom*; and consequently absurd. I pray, your sixth *Axiom*.

*B.* *Axiom VI. No Matter, Substance, or Essence of any Thing, is capable of being reduced to mere Nothing, or annihilated.*

*A.* True likewise; for if Something could be converted into Nothing, then would Nothing have a Property, contrary to *Axiom I*. Also, as it is impossible for a Thing to be, and not to be, in the same Moment; therefore, between the Time of its Being and Not-being, there must be some intermediate State of Existence, contrary to *Axiom III*. Please to relate your next *Axiom*.

*B.* *Axiom VII. Every Effect hath some Cause, pre-existent to itself.*

*A.* That I, and every Body else, must believe, or be absurd †. Pray deliver your next *Axiom*.

*B.* *Axiom*

\* This is the famous *Axiom* of the Philosophers, *Ex nihilo nihil gi gnitur*; and is so evident a Truth (as well as the following *Axiom*) that I wonder how any Person can think it unfit to be believed, or inserted here, which is a proper Place for it; since I cannot see that it contains any Thing *unreasonable* or *irreligious*, if it be granted that God cannot perform Impossibilities.

† For to say, that any one Thing is the Cause of itself, is to say  
say



B. *Axiom VIII.* If we ourselves are not the Cause of any Effect, then that Effect must depend on, and result from, some other Cause.

A. This is a plain Consequence of the foregoing; your next *Axiom*, if you please.

B. *Axiom IX.* All Things, as far as in them is, continue in the same State in which they began their Being.

A. I believe I take you right; you mean what was at first made *Straight, Crooked, Square, Round, &c.* would of themselves always persevere in that State, and of their own Accord would never assume any other Figure.

B. Very good; that is the full Meaning of the *Axiom*.

A. Pray let me hear your next.

B. *Axiom X.* Every Change is produced from some external Cause.

A. Most certainly; for suppose I see a Flower in full Bloom lie withered on the Ground, I presently conclude some external Cause hath made that Change in the Flower; which else would have continued vivid and fresh.

B. That's the Case. I have one *Axiom* more to propose, and that is,

*Axiom XI.* That every Change made in any Body, is always proportionable to the Powers of the Cause producing it. Thus the Motion of a Body is always in Proportion to the Greatness

say that it existed before it did exist, which is absurd; or else that its Existence was necessary, which can only be said of the Deity.

of

*of the Power, or Stroke, that put it first into Motion.*

*A.* And are there no other Maxims of this Science, that are necessary to be discoursed of before we go farther?

*B.* Those already related are sufficient for this Place; but as this Science depends on certain Principles, so it is likewise to be conducted by certain stated *Rules*.

*A.* I doubt not but this Part of Knowledge, which (according to the Notion I have of it) is very abstruse and difficult in many Parts, must require proper *Rules* and *Precepts* for a due Improvement, as well as most other Arts. Pray, *Sir*, then, what and how many are the *Rules* of *Philosophizing*?

*B.* They are in Number few, and are as follow, *viz.*

*Rule I.* We must take Care to admit no more Causes of natural Things than what are true, and sufficient to explain their *Phænomena*.

*Rule II.* We must observe always to assign the same Causes for the same natural Effects.

*Rule III.* Those Qualities which cannot be increased or diminished, and agree to all Bodies in which Experiments can be made, must be adjudged the Properties of all Bodies in general.

*Rule IV.* Propositions and Conclusions, deduced from actual Experiments, must be esteemed true and accurate, notwithstanding any

any *Hypotheses*, or received *Suppositions*, to the contrary; and must be insisted on, till some other *Phænomena* either render them more accurate, or liable to Exception.

*A.* What is the Reason of the first *Rule*?

*B.* It is founded on this Principle: Nature doth nothing in vain; but it is in vain to do that by many Means, which may be done by fewer: Now Nature is simple, and never luxuriates in superfluous Causes of Things. Therefore, &c.

*A.* That's exceeding good, indeed. Pray illustrate the second *Rule*.

*B.* By the second *Rule*, we are to assign the same Causes of Respiration in Beasts, as in Men; of Heat in Water, as in Fire; of Light in Fire, as in the Sun; and of the Reflection of Light in the Planets, as in the Earth, &c.

*A.* Pray give the Reasons of the third *Rule*.

*B.* The Qualities and Properties are not known to us but by Experiments; and therefore whatever we find to answer by all Experiments we can try, must be allowed an universal Property of all Bodies; on those on whom we cannot, as well as of those on whom we can, make Experiments: Nature being always contemporaneous and analogous to itself.

*A.* Indeed the Reason of the last *Rule* is so obvious, that, I think, none can doubt it; no Person being so perverse and preposterous, as to affirm there is more Reason

B

in



in a bare *Hypothesis*, than in *Facts* of *Experiments* \*.

B. Yet, it is strange, you'll say, that, by this very *Rule*, the System of the *Cartesian Philosophy* must fall; that *Burnet's Theory* of the *World* and *Deluge* must be valued at no greater Estimation, than an ingenious *Romance*: And thus must Mr. *Whiston's*, and all other *World-mongers* Systems and Theories, dissolve into a philosophical Nothing, which want actual and repeated Experiments to support them †.

\* These Rules, with the Reasons of them, are taken from Sir *Isaac Newton's Principia*.

† — *Monsieur des Cartes*, the great Master and Deliverer of the Philosophers from the Tyranny of *Aristotle*, is to be blamed for all this, for he has encouraged so very much the presumptuous Pride of Philosophers, that they think they understand all the Works of Nature, and are able to give a good Account of them; whereas neither He, nor any of his Followers, have given us a right Explication of any one Thing.—His great Fault was, that he made no Use at all of Geometry in Philosophy. *Keill's Introduction* to his Examination of Dr. *Burnet's Theory of the Earth*, Page 11, 12, 15.

Concerning Dr. *Burnet's Theory*, the same learned Gentleman observes, that—His rhetorical Expressions may easily captivate an incautious Reader, and make him swallow down for Truth, what I am apt to think the Author—design'd only for a philosophical Romance.—My Design therefore is to chuse out some of the principal Heads of the Theory, and having shewn them to be false and disagreeable to the Laws of *Mechanism*, the rest must all fall to the Ground of course. *Ibid.* Page 26, 27.

As for Mr. *Whiston's Theory*, he says—I believe it will be evident, by the following Considerations, that a Comet could never have produced these various Effects which Mr. *Whiston* has attributed to it; and it will also farther appear that the Deluge was the immediate Work of the Divine Power, and that no secondary Causes, without the Interposition of Omnipotence, could have brought such an Effect to pass. *Remarks on Mr. Whiston's Theory of the Earth*.

C H A P.

C H A P. IV.

*Of Hypothesis, of Experiments, of various Instruments for that Purpose, and their Uses.*

A. **A**RE any Kinds of *Hypothesis* to be admitted in reasoning about natural Subjects?

B. The Philosophers of the present Age hold them in vile Esteem, and will hardly admit the Name in their Writings; they think that which depends on bare Hypothesis and Conjecture, unworthy the Name of Philosophy; and therefore have framed new and more effectual Methods for philosophical Enquiries.

A. And must therefore a Philosopher in no wise have Recourse to Suppositions? May he not be admitted to say, he supposeth a Thing may be so or so? Or must he immediately assign an experimented Cause, or else directly confess his Ignorance? What are your Thoughts in this Matter?

B. Why I must confess, to discard all Hypothesis from *Physics*, is to reduce it within very narrow Limits; and in Truth, I think, it is falling from one Extreme to another; I am persuaded that Hypothesis duly qualified, if not absolutely necessary, yet may be very

B 2 subservient

subservient to natural Philosophy; and I know not what Kind of Philosophers we shall have in succeeding Ages, if they will receive no System of Philosophy, but what is wholly founded on mathematical Experiments and Demonstrations \*.

A. What Kind of Hypothesis, and how qualified, do you allow may be used in *Philosophy*?

B. They must have most or all of the following Qualifications.

1. They must be agreeable to just Reasoning.

2. They must be necessary for Want of Experience.

3. They must be consentaneous to Experience.

4. They must be sufficient to satisfy the *Phænomena*.

5. They must be naturally adapted to the Case.

6. They must be possible on every Account.

7. They must be probable in their own Nature.

8. They must be free from all Suspicion of Prejudice, Affection, or Prepossession, in their Author.

\* When the Reason or Cause of Things does not appear, it is much more ingenuous to acknowledge our Ignorance, than to advance absurd and extravagant Hypothesis, or, which is much worse, to have Recourse to *occult* (or *hidden*) *Causes and Qualities*, the infamous Refuge of a vain and ignorant Race of Philosophers.



*A.* I believe, *Sir*, few will deny you the Use of Hypothesis thus circumstanced and qualified: But pray, what Kinds of Demonstrations are those by Experiments, which you intimate they rely so much upon?

*B.* The very best all Nature can produce; they far exceed the keenest Glance of the Eye of Reason, and nothing but divine Revelation can inform us more truly of the intimate Natures of Things.

*A.* Very wonderful indeed! Happy the Age in which this Art received Improvements from such extraordinary Inventions. Pray, who were the first Authors of improving *Philosophy* by Experiments?

*B.* Their Names are recorded in the Book of Fame; have you not seen therein the glaring Characters of *Bacon*, *Boyle*, *Sir Isaac Newton*, *Woodward*, *Dr. Halley*, *Ray*, *Derham*, and several other exalted *Philosophers*? Some of whom are now living; and others subsist in marble Monuments to gratify the Curiosity of, and be admired by, all Posterity.

*A.* Yes, I have heard of those great Names you mention; but not being very conversant in the learned World, know but little about them; yet take an excessive Pleasure in hearing Relations of them, and the wonderful Things they have discovered.

*B.* I am glad to find in you such a Disposition, and question not but you will be highly gratified with the Series and Sequel of our Discourse.

*A.* I believe I shall; but to the Point: In what Manner, I pray you, are those Experiments performed? for, as you have seen the Manner thereof, you can well inform me.

*B.* They who have reduced experimental Philosophy to Method, and make it their Business to teach it others, prepare a large *Apparatus* of Instruments of all Kinds, to the Value of five or six hundred Pounds; and at stated Times, in a very large Room, there is an Operator appointed to perform a Course of Experiments therewith, in all the various Parts of natural Philosophy, in the open View of all who are present to see and learn the Manner thereof.

*A.* Cannot you give me some particular Account of those Instruments, and the Manner of using them?

*B.* It is the Subject of a large Volume to describe them with their Uses in particular: However, of such as are most common, to be had in the easiest Manner, and which you yourself may understand, and use if you please, you may take the following Account.

The *Telescope* is an optic Instrument, wherewith to view distant Objects, which it greatly enlargeth, and makes them seem near us; by which Means the Astronomers and Philosophers have made wonderful Discoveries in the Sun, Moon, and Planets \*.

The

\* The Word *Telescope* is derived from *τελέω*, to perfect, and *σκοπέω*, to view; as being an Instrument that perfects our View  
or

The *Microscope* is contrived to augment and render visible very minute and small Objects, which otherwise escape the Sight \*.

The *Helioscope* is a Sort of *Telescope*, fitted so, as to look on the Body of the Sun without Offence to the Eyes †.

The *Barometer*, or *Baroscope*, is contrived to estimate the small Variations of the Weight or Pressure of the Air ‡.

The

or Sight of distant Objects, to the greatest Degree possible. *Telescopes* are of two Sorts; *Dioptrical*, which perform all by *Refraction*; and *Cata-dioptrical*, which perform by *Reflection* and *Refraction* jointly. Since the Surfaces of Bodies are increased in Proportion to the Squares of the Diameters or like Sides, the Light falling on them will be diminished in that Proportion; and consequently the more an Object is magnified, the more obscure also it appears: Thus if one Glass magnifies the Breadth or Length of an Object ten times more than another, it will appear indeed an 100 times bigger, but withal an 100 times less bright than in the other. Therefore the more a *Telescope* exceeds the Length of five or six Feet, the worse it is for viewing *Terrestrial* Bodies; but for *Celestial* ones, the greatest Magnifier is the best, because their Light cannot be lessened to any Disadvantage, it being so very great.

\* *Microscope* is compounded of μικρός, small, and σκοπέω, to view; because by it small Objects are apparently magnified to the Sight. In this, also, the larger the Object is made to appear, the more obscure it will be; and therefore in large Magnifiers, it is necessary to illumine the Object very strongly with the Light of the Sun or Candle, by means of a *Lens*, or reflecting *Mirror*.

† *Helioscope*, from ἥλιος, the Sun, and σκοπέω, to view; it is best made by smoking a Piece of Glass with a Candle, and putting it before the Eye-Glass of a *Telescope* next the Eye; for then the Sun may be viewed in his Meridian Splendour without the least Offence.

‡ *Barometer* is so called of βάρος, Weight, and μετρέω, to measure; because it measures the Heaviness or Weight of the Atmosphere. The common *Barometer* (called the *Torricellian Tube*, from its Inventor *Torricellius* an *Italian*) is a Glass Tube of



24 *The* PHILOSOPHICAL GRAMMAR.

The *Anemoscope* is an Instrument, invented to foreflew the Change of the Air or Wind \*.

The *Æolipile* is contrived to shew the Nature and Force of pent-up Air, rarefied and breaking forth, resembling a Tempest, † &c.

about three Feet in Length, and  $\frac{1}{10}$  or  $\frac{2}{10}$  of an Inch Bore, hermetically sealed at one End, and at the other it is filled quite full of Quicksilver; and thus immerfed in a small Vessel of Quicksilver, that in the Tube will sink down, or run out into the Vessel till it remains in the Tube between 28 and 31 Inches perpendicular Height; and this Column of Mercury in the Tube is equal in Weight to a Column of Air of the same Base, and of the Height of the Atmosphere, and consequently is suspended by it; which therefore, by its rising higher or falling lower, shews the proportionally greater or lesser Weight or Pressure of the Atmosphere. Now since the Difference of the least and greatest perpendicular Height is in this Tube but about three Inches, therefore divers Contrivances have been made to render this Motion of greater Length in some other Direction, that thereby the Variation of the Air's Weight might be rendered more sensible, or more exactly measured: Hence arose divers Kinds of this Instrument, as the *Diagonal*, the *Wheel*, the *Machine*, &c. in *Barometers*; for a large Account of which, see *Harris's Lexicon*, or *Rowning's* Dissertation on the Barometer.

\* *Anemoscope*, from ἀνέμος, the Wind, and σκοπέω, to view; because by it we see what Point or Part of the Horizon the Wind is upon at any Time. A very good *Anemoscope* may be made on the Top of the House (affected directly by the Wind on all Sides) by means of an Iron Rod standing a considerable Height in the Air, with a Vane fixed on the Top to render it versatile; the lower End of which descending, the Covering shall have a large Index or Hand, turning upon the Cieling of the Room, in the Center of the *Compass* duly described thereon; for then the *Index* will always shew the Point to and from which the Wind blows.

† *Æolipile* (from Ἄελλε πύλαι, the Gates of *Æolus*, the God of the Winds) is a small hollow Globe of Brass, &c. with a small Neck and Hole, which being heated red hot, and thrown into a Vessel of Water, the Water will rush into the Cavity almost void of Air, and fill it; the Ball then set on the Fire again, the Water will be forced out, in vaporous Steams, with great Noise and Violence, and by Fits, by the Rarefaction and Spring of the internal heated Air.

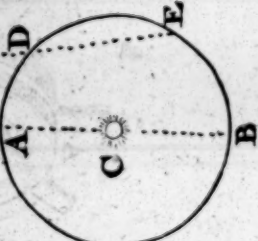
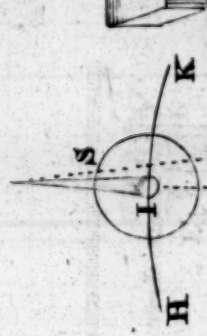
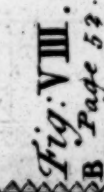
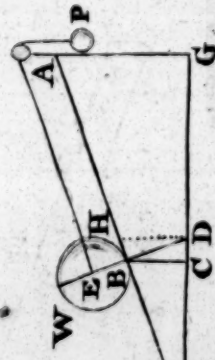
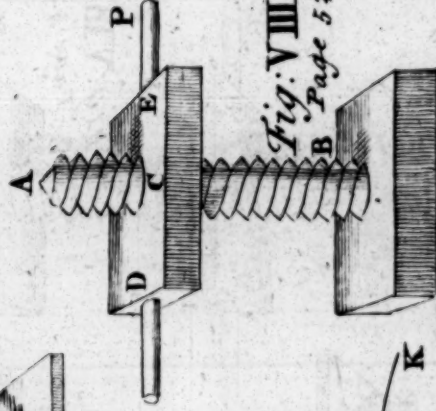
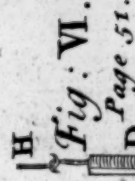
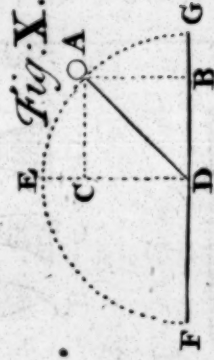
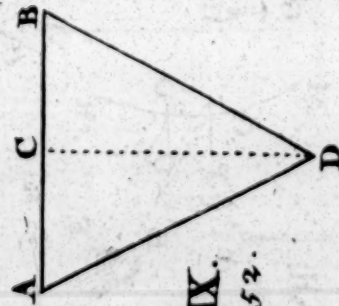
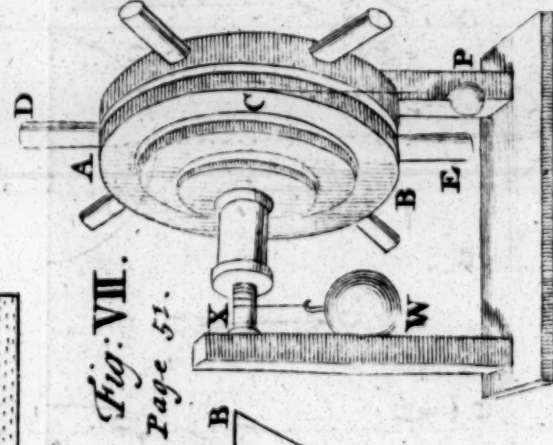
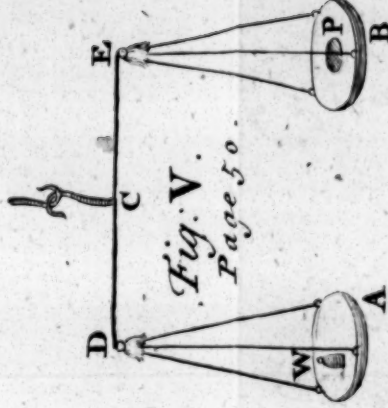
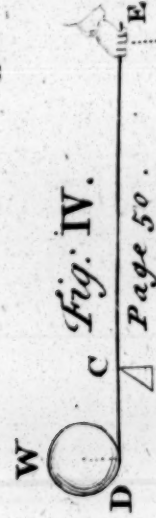
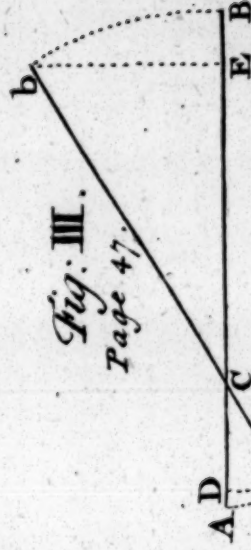
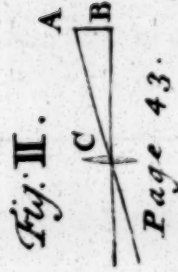
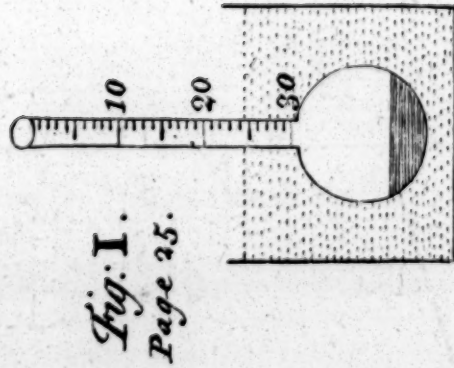
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To front Page 25.

Plate I.





*Various Instruments described.* 25

The *Areometer* is an Instrument to measure the specific Gravity of Liquids \*.

The *Hygroscope* is an Instrument to shew the Moisture and Dryness of the Air †.

The *Thermometer* measureth the Degrees of Heat and Cold in the Air ‡.

The

\* *Areometer*, I suppose, is from ἀραιός, rare, and μετρέω, to measure; tho' it measures not the *Rarity*, but *Gravity* of Liquids. The common *Areometer*, or Water-Poise, is made of thin Glass, of the Form represented in *Plate I. Fig. 1.* fronting p. 25, which being hollow, receives so much Mercury as will keep it swimming in an erect Position; then the Stem being nicely graduated, the Surface of the Liquids, into which it is immersed, will cut off more or fewer Degrees; that is, the Ball will sink more or less, as the Liquids are severally of a lesser or greater Gravity. A new *Areometer* is described in *Philos. Trans. N° 262*, which see.

† *Hygroscope* (derived of ὑγρός, moist, and σκοπέω, to view) is an useful Instrument to be made several Ways. The easiest and best of all is that made with a String of Whipcord fastened to a Hook in the Cieling, and at the lower End of which is fixed a Weight of about half a Pound, with an Index at the Bottom thereof a Foot long; and under it a Table, &c. with a large Circle divided into an 100 equal Parts or Degrees, so fitted, that the Center of the Index hangs just over the Center of the Circle. For this, after the String has been duly stretched, nicely shews, by its Twisting and Contraction, the *Moisture*, and by untwisting and lengthening, the *Dryness* of the Air, in the Motion of the Index this Way and that over the small Divisions of the Circle. See several other Kinds in *Harris's Lex. Tech.* under the Word *Hygroscope*.

‡ *Thermometer* comes from θερμή, Warmth, and μετρέω, to measure; the common Sort is the best, which is generally added to the *Barometer*. It consists of a Glass Tube filled with Spirit of Wine of a red Tincture; in making it, the Tube is heated very much in the Flame of a Candle, which causes a *Vacuum* in some Degree therein; then immediately the open End is dipt into the said Spirit in a Vessel, which, by the Pressure of the Air, is made to ascend therein, till the Ball and Tube-part be filled to a necessary Height. Then having a Piece of Paper &c. graduated from a certain Point on each Side, to 100 Degrees, put the Ball into Water just beginning to freeze, and place the Surface of the Spirit in the Tube at that Time against

The *Hydrostatic* Balance, is an exceeding exact fine Pair of Scales for making Experiments, relating to the Gravity of Fluids \*.

*Dioptric* Instruments of various Sorts explain the Nature of refracted Rays of Light through various Mediums †.

*Catoptric* Instruments are also manifold, which shew the Nature of reflected Rays of Light ‡.

The *Pneumatic* Engine, called the *Air-Pump*, is the most universal of all others; it is the very Basis of the Philosophy of the Air, and hath opened a greater Door to the Secrets of Nature, than any Thing that was ever invented besides ||.

The

the (o) in a graduated Line, and the Thermometer is adjusted for Use. This is an Instrument of admirable Use in the Hands of a skilful Person, in discovering the Degrees of Heat and Cold in Air, Animal and Vegetable Bodies, Liquids, Hot-beds, &c. See a farther Account hereof in Dr. *Hook's Micrograph*. Page 38, &c.

\* *Hydrostatic* is from ὕδωρ, Water, and σταλιν, the Art of Weighing. The Instrument I make use of for finding the specific Gravity of Solids and Fluids is different from, and much better than, the common Hydrostatic Balance, as I shall shew when I am arrived at that Part of Philosophy.

† *Dioptric* (of διόπτωμαι, to see thro' any Thing) is a Term applied to all Optic Instruments which consist of Lenses, one or more; as *Telescopes*, *Microscopes*, *Magic Lanthorns*, and *Camera Obscura*, &c. because by them we see Objects thro' the Medium of Glass, i. e. by Rays refracted through the Lenses.

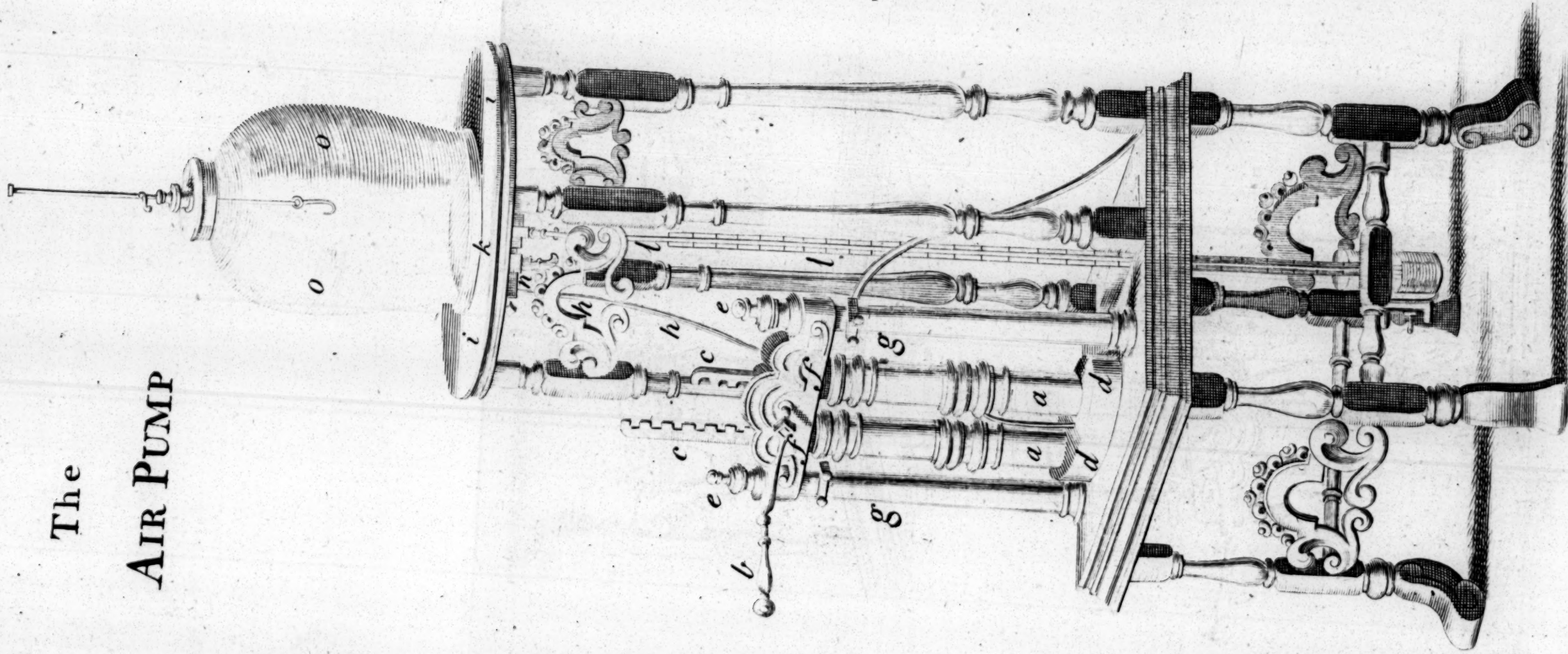
‡ *Catoptric* (κατόπτρον, a Mirrour) is a Term applied to all Kinds of Glass, &c. Mirrours, whether *plane*, *convex*, *concave*, *circular*, *cylindrical*, &c. because by them we see Objects by Rays of Light reflected from their Surface, which is called *Reflex Vision*.

|| *Pneumatic* is from πνεῦμα, Spirit, Air, Wind; because the *Air-Pump* exhausts the *Air* out of Bodies, placed in a proper Vessel, called a Receiver.





The  
AIR PUMP



The Orrery, which shews the Movements of all the Heavenly Bodies in the Solar System about the Sun (by a noble Piece of Mechanism) all the Phænomena whereof are nicely corresponding to the Truth\*.

A Description of this most surprising and useful Engine, according to Mr. *Hawksbee's* Improvement thereof, take as follows.

The whole Structure of the *Air-Pump*, in which *a, a* are two strong hollow Barrels, or Tubes of Brass, in which two *Emboli*, or Suckers, are moved up and down by their Racks *c, c*, in whose Notches a Cog-wheel falls, which moves upon the Axis *f*, when the Winch *b* is turned; *g, g* are two Pillars of Wood fixed on the Frame at Bottom, and having Screws at Top on which the Nuts *e, e* do run, and press down the Piece *f, f* upon the Tops of the Barrels, to fix them at *Top* and *Bottom*; *h, h* is a Swan-necked hollow Brass-Pipe, which communicates with an hollow Brass Piece *n* above, and another in the Box *d, d* below; the Piece *n* also opens into the Cavity of the Receiver *o, o*, by a small Hole in the Top Plate *i, i*, on which it is placed: Also the Pipe in the Box *d, d* communicates at each End by a small Tube with the Barrels *g, g*; and thus there is a Communication between the Barrels and the Receiver *o, o*, by which Means, the Air in the latter is exhausted by the Suckers of the former. Moreover, *l, l* is a Gage, being a Barometer with its Bason of Mercury in, and its boxen Index graduated into Inches and (above 28) the Tenths of an Inch; this Index is set on a Piece of Cork which floats on the Surface of the Mercury, that it may rise and fall with it, and so exactly measure the Height of the Mercury in the Tube above the Surface of that in the Bason. For this Barometer is open at Top, and communicates with the Receiver, so that the greater or lesser Quantity of Air therein is shewn by the lesser or greater Height of Mercury in the Tube. In the Pipe *n* is a Stop-cock, that also communicates with the Receiver, and either excludes or re-admits the Air, as Occasion requires. On the Brass Plates *k*, at the Top of the Frame, are placed wet Leathers to set the Receiver upon, which effectually exclude all the external Air, while the internal is exhausting by the Operator. And this is the Construction of the *Air-Pump* in common Use. All which is exemplified by the Copper-Plate II. representing an *Air-Pump*, and fronting this Page.

\* See the Figure of the Orrery published by Mr. *Thomas Heath*.

A. Sure,



*A.* Sure, wonderfully curious and delightful must it then be, to see all those extraordinary Things performed by such nice Instruments! Alas! how great is the Ignorance of the Generality of Mankind! what wretched, unworthy, and uncouth Notions have we conceived of the World and Things therein! We think ourselves learned, if we know how to find out a Word in *Bailey's* Dictionary, little dreaming so much Pains, Expence, and Time, necessary to acquire but a partial Knowledge, and to be esteemed but moderately learned!

*B.* Well, but don't be discouraged; the Knowledge of these Things will be much easier and cheaper to us, than they were to our Forefathers; what cost them Pounds, we may have for so many Pence; what cost them Years of Study, Fatigue and Disquietude, we may acquire with Ease and Pleasure in a few Days or Months; what they rejoiced to come at by Piece-meals, and in an imperfect Manner, we have presented, as in one entire methodical View. Wherefore, if we are ignorant, it is because we are idle and indolent indeed: If we live satisfied only with the vulgar erroneous Notions of fallacious Sense, and endeavour not to rectify them by the Precepts of refined and learned Reason, and the Methods put into our Power; in vain then hath God given us Ability to be *wiser than the Fowls of Heaven, and to have more Understanding than the Beasts which perish.*





T H E

*Philosophical Grammar:*

Or, VIEW of

Modern Philosophy.

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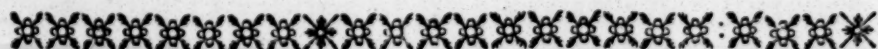
P A R T I.

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S O M A T O L O G Y :

O R,

DOCTRINE of the Universal Properties  
of MATTER; and the specific Qua-  
lities of natural BODIES ; with Sir  
*ISAAC NEWTON*'s Laws of  
Nature.



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Psychology - General  
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Modern Psychology

PART I

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C H A P. I.

SOMATOLOGY, *treating of the common Nature and Properties of all natural Bodies.*

A. **W**HAT do you call *Somatology*?

B. That Part of *Physiology* which treateth of Matter or Substance in general, with the Nature and inseparable Properties of all Bodies consisting thereof.

A. What is implied in the Original of the Word *Somatology*?

B. The very same Thing; for it is composed of the two Greek Words, σώματα, *Bodies*, and λόγος, *a Discourse*; i. e. *a Discourse of natural Bodies.*

A. What do you mean by *Matter*?

B. The *Substance*, or *Essence*, of which all Things in the Universe consist.

A. Is there any Difference between what you call *Matter* and *Body*?

B. No; excepting only, that the latter is used often in the *Plural*, for the several small Parts and Divisions of the common Substance of the Universe; i. e. they are called *Bodies.*

A. Is the *intimate* Nature of Matter to be known?

B. No;



32 *The PHILOSOPHICAL GRAMMAR.*

B. No; this is concealed from human Knowledge; all we can discover of natural Bodies, are some few Properties and Affections thereof, which are more obvious to our Senses.

A. Is the Matter of all Bodies the same?

B. Yes; what the Philosophers call the primary constituent *Particles, Atoms, or Corpuscles* of Matter, which constitute Bodies of infinite Kinds, are yet the same, or of the same Nature, among themselves, in all those Bodies \*.

A. And is not this the same Thing as to say, that *Fire* and *Water*, a *Flint* and *Down*, *Gold* and *Dung*, &c. are the same Things with respect to the Matter of which they consist?

B. Yes, they are so; and what thence do you infer?

A. What then; why then, I believe, you will have few Disciples amongst the common People; and several will think they give it a

\* Dr. Woodward asserts Matter to be originally and really very different; being at its first Creation divided into several *Ranks, Sets, or Kinds of Corpuscles*; that those of the *same Kind* are every where alike and uniform; but those of *different Kinds*, differ not only in *Substance*, but in all the *Qualities* observable in Bodies compounded of them. And that from hence arise the Differences in Colour, Taste, Smell, Hardness, Gravity, &c. in all Bodies. See his Essay towards a natural History of the Earth, Part v. p. 229, 230. This is the Doctrine also of the *Cartesians*, tho' abundantly confuted by the *Newtonians*. See *Newt. Princip.* p. 388. *Optics*, p. 313. *Musschenbroek's Elem. Phys.* Matth. § 61, 83, 383. *Cheyne's Phil. Princip.* p. 59. *Boyle* on the Principles of natural Bodies. *Ray* on the Creat. p. 68, 85. *Keill's Introd. ad ver. Phys.* Sect. viii.

better Term than it deserves, if they call such Assertions *philosophical Romancing*.

B. It is very probable, that it may be so; but the real Nature and unchangeable Truth of Things are still to be insisted on, though they are unknown to, and gain no Credit with, the Vulgar.

A. Is Matter *finite*, or *infinite*?

B. *Finite*; and limited within certain Spaces and Bounds, in the various Parts of the Universe\*.

A. How is Matter, or Body, commonly considered?

B. As having three Dimensions, *viz. Length, Breadth, and Thickness*.

A. Is this Consideration of Matter the most philosophical?

B. No; it is too vulgar and defective.

A. What is a more accurate Method to acquire the best Knowledge and Ideas of Matter, or Bodies, that we are capable of?

B. By considering those Properties and Affections thereof, which are obvious to us, and best known by us.

A. How are the Properties of Bodies distinguished?

B. Into those which are common to all alike, and those which are peculiar to each in

\* The *Cartesians* absurdly place the Essence of Matter in *Extension*, and consequently make it *infinite*, as being then the same as Space itself. But the *Newtonians* placing it in *solid impenetrable Corpuscles*, or *Atoms*, make it *finite*. See *Newt. Princip.* p. 316. *Cotes's Pref.* thereto. *Musschenbroek*, Part i. Chap. iv. *Keill's Introd. Lect. ii.* *Clarke's Notes on Robault*, p. 22.

particular : The first are called Common and Essential, the latter Specific and Accidental.

*A.* Which are the Properties of the first Sort ?

*B.* They are generally reckoned those which follow :

I. *Extension*, for all Bodies are extended.

II. *Divisibility*, for all Bodies may be divided.

III. *Solidity*, for the Particles of all Bodies are hard.

IV. *Figurability*, for all Bodies have some Form or Figure.

V. *Mobility*, for all Bodies are capable of being moved.

*A.* Is this Enumeration of the common Properties of Bodies every Way just, and equal in all Things ?

*B.* No, I do not think it is ; for, first, they may all be asserted of the whole Body, except *Solidity*, which agrees only to the Particles of Bodies : Again, other Properties may as universally be asserted of Bodies as some of these, as *Durability* ; for a Body is no less infinitely durable, from its Nature, than it is infinitely divisible.

*A.* Which are those other Properties of Bodies, which you call *Specific* or *Accidental* ?

*B.* They are generally reckoned the following :

I. *Light*.



- I. *Light.*
- II. *Colours.*
- III. *Sound.*
- IV. *Gravity and Levity.*
- V. *Attraction and Electricity.*
- VI. *Transparency and Opacity.*
- VII. *Density and Rarity.*
- VIII. *Hardness and Softness.*
- IX. *Rigidity and Flexibility.*
- X. *Consistence and Fluidity.*
- XI. *Heat and Cold.*
- XII. *Humidity and Siccity.*
- XIII. *Elasticity.*
- XIV. *Odours and Sapours.*

*A.* What do you call the *Elements* of natural Bodies ?

*B.* Those pure and simple Substances, of which all gross and mixed Bodies are said to consist ; and into which they may ultimately be resolved, or reduced.

*A.* How many are those Elements ?

*B.* The Ancients counted seven, *viz.* *Fire, Air, Water, Earth, Salt, Sulphur, and Mercury.*

*A.* How many do the Moderns reckon ?

*B.* Some of the modern chymical Philosophers reckon five, *viz.* *Mercury, Phlegm, Sulphur, Salt, and Earth.* Others reduce them to three, *viz.* *Mercury, Sulphur, and Salt.* Whereas, in Reality, there are no other Elements of natural Bodies than the primogenial Particles of Matter, or Substance, of

which they consist universally, and endued with the Properties above mentioned \*.

## C H A P. II.

*Of* EXTENSION, *and the* MAGNITUDE  
*and* DIMENSIONS *of natural* BODIES.

*A.* **I** Remember you said, the first of the universal and essential Properties of Matter, or Body, was *Extension*; pray explain what is meant thereby.

*B.* *Extension* of Matter, is the Quantity of Bulk, or Size, into which the primogenial Particles of Matter are distributed, or extended, in any natural Body.

*A.* What ariseth hence?

*B.* The Doctrine of Magnitude, and Dimension of Bodies.

*A.* What do you call the Magnitude of Bodies?

*B.* Their Size, or Bulk, or Quantity of Space, which they take up.

*A.* How do you compute, or estimate the Magnitude of Bodies?

*B.* By the Quantity of their Dimensions.

*A.* What do you call the *Dimensions* of Bodies?

\* That there is but *one Element* of all Bodies, *viz. Substance*, or *Matter*, is largely shewn by the Authors quoted in Page 33.

*B.* Their

*Of Magnitude and Dimensions of Bodies.* 37

B. Their *Extension* in *Length*, *Breadth*, and *Thicknefs*, or *Depth*; and these are the common Terms, or Bounds, which limit the Substance of all Bodies.

A. Have all Bodies these three Dimensions?

B. Yes, they have; though one, or two, or all of them, escape our Senses; yet, they nevertheless exist together in all Bodies.

A. How do some then say that a Point hath no Dimensions?

B. They mean by this, a Point, or the smallest Part of Space, which, naturally speaking, is *Nothing*, and therefore hath no Properties.

A. How are Bodies differenced, with respect to their Dimensions?

B. They are by Mathematicians, on that Account, distributed into *Points*, *Lines*, *Superficies*, and *Solids*.

A. As how?

B. They call that a *Point*, when all the three Dimensions are so very small, as to be altogether imperceptible, as the Speck A: A *Line*, is that which appears to have no Breadth or Thicknefs, as BC: A *Superficies*, that which hath Length and Breadth, but no perceivable Thicknefs, as ABCD: *Lastly*, they call that a *Solid*, which hath evidently all the three Dimensions, as the Solid S; whose Length is AC, its Breadth AB, and its Thicknefs, or Depth, AE. See *Fig. I, II, III, and IV.* on *Plate IV*, fronting p. 70.

A. How many are the *Degrees* of *Magnitude*?

C 3

B. They



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*B.* They are infinite ; for no Body, however great or small, can be given, but another may be conceived greater or smaller than it ; as I shall demonstrate to you when we discourse of the *Divisibility* of Matter.

*A.* How are Bodies, or Things, said to be, *great* or *small* ?

*B.* *Greatness*, or *Smallness*, are only relative Terms ; and Things are great or small only, as they are compared one with another : Thus a Mountain two or three Miles high, is a great one, and one not above two or three Perches high, is a small one, when they are compared together.

*A.* Then, I suppose, you count it improper and unphilosophical, to say any Thing is *absolutely great* or *small* ?

*B.* Most certainly it is ; because the same Thing is either great or small by Comparison only : Thus a *Hog* is a small Creature, compared with the largest *Elephant* ; but it is a great Creature, when compared with a *Louse* that crawls on his Back.

## C H A P. III.

*Of the DIVISIBILITY of Matter, of the INFINITY thereof, and of the wonderful DUCTILITY and DIVISIBILITY of several BODIES.*

*A.* **W**HAT is the *Divisibility* of Matter?

*B.* It is that universal Property or Disposition of a Body, whereby it is capable of being divided or reduced into Parts, either actually or mentally.

*A.* How far are Bodies capable of being divided?

*B.* A Body is divisible in *infinitum*, or without End.

*A.* This is a wonderful Doctrine! What will you say, that a very small Particle of Matter is capable of being divided into Parts still lesser and lesser, through all the Ages of Eternity?

*B.* Yes; and as wonderful as it is, it is capable of no less than a plain mathematical Demonstration.

*A.* Do you say so! I wish it may be such as I can understand; pray let me see it, however.

*B.* I will, and I'll engage that you or any one may understand it; and it is thus. Let EF (*Fig. V. on Plate IV, fronting p. 70.*) be a right Line,

C 4

I say,

I say, that Line may be divided into a Number of Parts, exceeding any finite Number; and it is thus demonstrated. Through E and F, the two Extremities of the Line, let there be drawn the two parallel Lines AB, CD; and suppose they were infinitely extended to the right Hand, then it is evident, that in the Line CD, infinitely extended, there may be taken an infinite Number of Points, *a, b, c, d, e, &c.* Now if to each of those Points there be drawn straight Lines from the Point A (taken in AB, to the left of the given Line EF) each of those Lines *Aa, Ab, Ac, &c.* will cut off a small Portion of the Line EF; but because the Points *a, b, c, &c.* are infinite in Number, so likewise are the Lines *Aa, Ab, Ac, &c.* and consequently the Parts, or small Portions, they will cut off of the Line EF, will be infinite in Number also; and thus it is manifest, that the Line EF, however small, may yet be divided into an infinite Number of Parts \*.

*A.* Indeed it is so plain, that I must confess and believe it: And what may we infer from this wonderful Property of Matter?

*B. First,* That the least Particle of Matter is capable of an infinite Division, as well as the greatest.

\* For is impossible that all the Parts of the Line EF, or the least Particle thereof next E, should be cut off, unless we can draw a Line from the Point A to the Line CD which shall at the same Time coincide with AB: But that this is impossible, every *Työ* in Geometry can easily conceive and demonstrate. See this Property in various Ways demonstrated by Dr. *Keill*, in his third and fourth Lectures in his Introduction to Natural Philosophy.

*Secondly,*



*Secondly*, That there is no such thing as infinitely small Particles of Matter.

*Thirdly*, That the original or primogenial Particles of Matter, into which it may be ultimately reduced, are altogether past human Comprehension.

*Fourthly*, Hence we learn what wonderful Effects a small Piece of Matter may produce by its *Divisibility* and *Ductility*.

*A.* What do you call the *Ductility* of Matter?

*B.* That Disposition of it, whereby it is easily drawn out into Length, or Breadth.

*A.* What curious and extraordinary Instances have you of this Kind?

*B.* I think the following very remarkable, *viz.*

Mr. *Boyle* saith, a Piece of Silk, weighing two Grains and a half only, was drawn out into a Thread three hundred Yards long.

He saith also, that one Grain of Gold may be beat into a Leaf of fifty square Inches.

If then an Inch in Length be divided into two hundred Parts, the Eye may distinguish them all; wherefore in one Grain of Gold are 2000000 of visible Parts.

An Ounce of Silver may be gilt with eight Grains of Gold, which afterwards may be drawn out into a Wire of 1300 Feet long.

Dr. *Halley* has made it appear, that 124500 of those very fine Skins of Gold, used in gilding

*A.* These Things are very admirable indeed. What other remarkable Discoveries have issued from the Divisibility of Matter ?

B. The extraordinary Subtlety of Matter, and the Tenuity or Fineness of its Parts, will appear by these Instances.

*A.* Mr. Boyle hath found, that one Grain of Copper will tinge 28534 Grains of Water; and therefore in a Drop of Water, whose Diameter is one hundredth of an Inch, there are contained 211400 visible Parts of Copper, reckoning only an 100 to an Inch.

Again, Dr. Keill hath computed the Magnitude of a Particle of *Affa Fætida*, to be  $\frac{38}{10000000000000000}$  Parts of a Cubic Inch.

He has likewise shewn, that one of those Globules of Blood, which circulate in the Veins of some very small Creatures, doth not exceed the  Parts of a Cubic Inch.

[illegible]

*Lastly*, He hath shewn the least Particle of Matter shall be made to fill the greatest Space (suppose the Orb of *Saturn*) so that there shall be no Pore therein, whose Diameter





## C H A P. IV.

*Of the SOLIDITY and FIGURABILITY  
of BODIES.*

*A.* **W**HAT is that common Property of Matter, or Body, which you call *Solidity*?

*B.* *Solidity* is that Property, whereby a Body resisteth all others that press it on every Side, and whereby it hinders all other Bodies from entering into that Place which it possesseth, though they are forced against it ever so violently.

*A.* Then suppose I press a Body ever so forcibly between my Hands, that Property which prevents my Hands from coming to a mutual Contact, you call *Solidity*, if I understand you right?

*B.* Yes, I do so; and this Property is the Ground or Cause of all Resistance in Bodies.

*A.* Is not this a new Term for this Property?

*B.* Yes, it hath been formerly called *Impenetrability*; because two Bodies cannot penetrate each other, or be in the same Place at once\*.

\* Some have compounded these two Terms, and called this Property of Matter *Impenetrable Solidity*; and which does certainly better express it than either of the Words singly.

*A.* And

*Of Solidity and the Figure of Bodies.* 45

A. And is this Property of Matter the same in liquid or fluid Bodies, as it is in hard or fixed ones?

B. The very same; for a Drop of Water, or a Particle of Air, remaining fixed between any two Bodies, will no less hinder their Contact, than an equal Quantity of Steel or Diamond would do.

A. Pray what is that you call Figurability of Body or Matter?

B. That universal Disposition thereof, whereby it is necessitated to appear in, or put on some Sort of *Shape*, or *Figure*, or other.

A. Wherein doth the *Shape* or *Figure* of Matter consist?

B. In the Manner, or Mode, or Fashion, of its Extremities, or external Superficies, within which it is contained.

A. Is it not the same with what is called the *Form* or *Modification* of Matter?

B. Yes; and since the Forms of Matter are only the Shape, or Fashion, of its terminating Extremities, we must exclude *substantial Forms*, as the *contradictious Nonsense* and *Jargon* of the Schools\*.

A. Doth this Property of Matter you now discourse of, equally relate to the original

\* The Doctrine of *Substantial Forms* is doubly absurd, because it teaches that *Form is itself a Substance*, and yet incorporeal, and of itself incapable of Quantity, Dimension, and Division. They are certainly poor *Ontologists*, as well as *Philosophers*, who talk at this Rate. Let those who would see a great deal to little Purpose said on this Head, read *Sennertus's* Epitome of Natural Science, *Lib. i. Cap. 3.*

primogenial Particles of Matter, as well as to the groffer Composition thereof in natural Bodies?

*B.* Yes; but in these inconceivable Particles of Matter, the Forms, no doubt, are much more simple, regular, and determinate, than in those heterogeneous Compositions which we are acquainted withal.

## C H A P. V.

### *Of MOBILITY of Matter, and the Nature of MOTION and REST.*

*A.* **P**RAY what is meant by the *Mobility* of Matter?

*B.* It is that essential Property, whereby any Part of Matter is capable of *Motion*, or being moved.

*A.* What is *Motion*?

*B.* A continual and successive Change of Place.

*A.* What is *Rest*?

*B.* The Continuance of a Body in the same Place, for any Time.

*A.* What is the *Cause* of Motion?

*B.* An external Force or Power applied to any Body; which being superiour to its Resistance, impelleth or driveth it out of its Place\*.

*A.* How

\* Motion may be considered, (1.) as *absolutely free*, or at least so far as to be affected with nothing but the Resistance of the Medium



*Of Mobility, and the Nature of Motion.* 47

A. How is Motion distinguished?

B. Into *absolute* and *relative*.

A. What is *absolute Motion*?

B. The real Motion of a Body, from one Part of absolute Space to another.

A. What do you call *relative Motion*?

B. It is the Change of Place, with Respect to some other Things at Rest: And absolute and relative Rest is just the contrary to these.

A. What do you observe hence?

B. That a Person may relatively be at Rest, who yet is really and truly in absolute Motion.

A. Please to exemplify this Matter.

B. I will. Suppose a Person seated in a Ship, he appeareth to all within the Ship to be at Rest; though at the same Time he is moved with the same Motion, with the same Swiftnes, and according to the same Course, as the Ship itself is, with regard to absolute Space.

A. What are the general Affections of Motion?

B. They are these three, *viz.*

1. The *Celerity* or *Velocity* of Motion.

2. The *Quantity* of Motion.

3. The *Direction* of Motion.

Medium thro' which the moving Body passes. (2.) As *determinate*, and under *restraint*, when the moving Body is obliged to move upon or about a *fixed Point*, which is called the *Center of Motion*. Thus, suppose the Line AB be moved on the Center C into any other Position, as *ab*; the Point C is said to be the Center of that Motion. See *Fig. III.* on *Plate I.* fronting p. 25.

A. What

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*A.* What do you mean by the *Celerity* of *Motion*?

*B.* It is that whereby a Body passeth over a given Space, in a given Time: So that if in one Minute a Body *A* passeth over the Space *ab*, and another Body *B* passeth over the Space *cd*, in the same Time; then the *Celerity* or *Swiftness* of the Body *A* will be to the *Celerity* of the Body *B*, as the Line *ab* is to the Line *cd*. See *Fig. VI.* \* on *Plate IV*, fronting *p. 70*.

*A.* How do you compute the *Quantity* of *Motion*?

*B.* By compounding the Proportion of the Quantity of Matter, and the Velocity of Motion. Thus, if the Body *A* hath two Parts of

\* That is, the *Celerities* are to each other, as the Spaces passed thro' by the moving Bodies. And thus, while *AB* is moving into the Situation *ab*, the Point *B* will describe the circular Arch *Bb*, in the same Time that *A* describes the Arch *Aa*; and consequently the *Celerity* of the Motion of the Point *B* will be to that of the Point *A*, as the Length of the Arch *Bb* is to the Length of the Arch *Aa*, as being the Spaces passed thro' in the same Time; and this is the Foundation of all *Mechanics*, or the Science of Motion.

Now the Arch *Bb* is to the Arch *Aa*, as *Cb* is to *Ca*; for they are the *Radii* by which these Arches are described. From *b* and *a* let fall the Perpendiculars *bE* and *aD* on the Line *AB*; then in the similar Triangles *aCD* and *bCE*, we have *bC* to *aC*, as *CE* to *CD*; and therefore the Arch *bB* is to the Arch *aA*, as *CE* is to *CD*; consequently, if any heavy Body were placed on the Point *B*, and another on the Point *A*, since all heavy Bodies, at Liberty, tend to the Earth in perpendicular Directions, while the Line *AB* is raised to the Situation *ab*, the Weights would, according to their proper Direction, or Propension, be moved thro' the Spaces *bE* and *aD* only; and so their Velocities, or the Spaces they pass thro' round the Point *C*, will always be proportional to the least Distances *CE* and *CD*, of their proper Directions *bE* and *aD*, from the said Center of Motion *C*.

Matter,

Matter, and six Degrees of Velocity, the Motion of that Body will be twelve. See *Fig. VII.* \* on *Plate IV*, fronting *p. 70*.

*A.* Then by this Means I perceive you have an easy Method of comparing the Quantity of Motion in any two or more Bodies?

*B.* Yes, very truly: For, suppose the Body *A* hath two Parts of Matter, and six Degrees of Velocity; and the Body *B* hath four Parts of Matter, and ten Degrees of Velocity; then the Quantity of Motion in *A*, passing from *a* to *b*, will be to the Quantity of Motion in *B*, passing the Space *cd*, as 12 to 40. See *Fig. VII.* on *Plate IV*, fronting *p. 70*.

*A.* Why then I find, that if the Quantity of Matter in any two Bodies be equal, and their Velocities unequal, and the contrary, their Quantity of Motion will likewise be unequal?

*B.* It will be so; for the Quantity of Motion in two Bodies will never be equal, if their Matter or Velocity differs, unless in this one Case, when the Quantities of Matter and Velocity are in reciprocal Proportion to each other: As thus,  $4 : 2 :: 6 : 3$ . Wherefore the Motion of *B*, with three Degrees of Velocity, is equal to the Motion of *A*, with six Degrees

\* What I here call the *Quantity* of Motion, Mechanical Philosophers call the *Momentum* or *Force* of Motion; by which they mean all the Power that can be given to any Body, by Means of any Machine in regard of the *Gravity* or *Velocity* thereof; from which two Principles, either *singly* or *compounded*, all the Force or Power of Bodies is derived.



thereof. See *Fig. VII.* \* on Plate IV, fronting p. 70.

## A. What

\* From hence the *Theory* or *Reason* of the Use and Advantage of every *Mechanical Power*, or *Machine*, is evident.

I. The LEVER, *Fig. IV.* of Plate I, fronting p. 25.

Let DE represent a *Lever*, moveable on the *Fulcrum* C; let P, a Weight of 2 Pounds, hang freely from the Point E, and W, a Weight of 8 Pounds, be placed on the Point D: Now if the Lever be moved, the Distance CE will represent the Celerity of the Body P, and CD that of the Body W, by Note (\*), in Page 40. Let CD be 3, and CE be 12: Then, since it is  $P : W :: CD : CE$ , *i. e.*  $2 : 8 :: 3 : 12$ , it is evident the Power P (2) with its Celerity CE (12), will be equivalent to the Weight W (8) and its Celerity CD (3); for the Bodies P, W, being in a reciprocal Proportion to their Celerities (or nearest Distances from the Center C) being equal (*viz.* 24) on each Side, make the Force on each Side equal; and consequently the Lever DE will not be moved, but remain in *Equilibrio*.

Therefore, if an Hand be applied to the Point E, and press on the Lever, with a Force any thing greater than that of 2 Pounds, it will raise the Weight W of 8 Pounds, placed as here supposed.

Now tho' there be Levers of several Sorts, what is here said is equally applicable to them all.

II. The BALANCE, *Fig. V.* of Plate I, fronting p. 25.

The Balance is a Machine for trying the Equality of Weights.

Let DE be the Beam of a Balance, suspended and moveable on the Point C, whose Arms (or *Brachia*) CD and CE are equal, as in a just Balance they should be; and A and B be two Scales hanging from the Points D and E: Now if any Standard Weight W be put in the Scale A, and any Thing, suppose P, a Cheese, be put in the other Scale B, and the Scales remain in *Equilibrio*, then is the Body P of the same Weight as W; because the Distances from the Center C (*viz.* CD and CE) are equal.

Therefore if the Scale A rise or descend, so much must be taken from, or added to the Body P, as will reduce the Scales to an

A. What do you call the *Direction* of Motion?

B. It

an *Equilibration*; as is always done in *buying* and *selling* by *Weight*.

III. The PULLEY, *Fig. VI. of Plate I, fronting p. 25.*

The Pulley is a Machine for raising Weights to a great Height.

Let DEGF be a *Tackle* of Pullies, in which D and E are fixed, and G, F move or rise and descend with the Weight W. Let any Power be applied to the Rope at P to raise the Weight W; now it is plain, that if the Weight W be raised one Foot, the Pullies F and G will each of them be raised one Foot, consequently the two Ropes R, S, belonging to F, and the other two T, V, belonging to G, will each be shortened one Foot; therefore four Feet will be lost in the four Ropes, R, S, T, V, all which will be gained by the Power P; or it will descend four Feet, while the Weight W rises one; and therefore the Velocity of the Power being four Times greater than that of the Weight, the Weight will be four Times greater than the Power, that at P will sustain it.

And in all Tackles of this Kind, the Power is to the Weight it sustains, as One or Unity to the Number of Ropes applied to the lower Pullies.

IV. The WHEEL and AXIS, *Fig. VII. of Plate I, fronting p. 25.*

Let ACB be a Wheel, in which is fixed the Axis X; now it is easy to conceive, that if any Power P be applied to the Circumference of the Wheel, in order to sustain a Weight W hanging from the Axis X, the Power P shall be to the Weight W, as the Circumference of the Axis to the Circumference of the Wheel. For while the Wheel turns once round, the Power P descends through a Space equal to the Circumference thereof, and the Weight in the same Time is raised thro' another Space equal to the Circumference of the Axis; but the *Celerities* are as the Space passed thro', and therefore as the Circumferences; whence the Proposition is evident.

But since the Circumferences of Circles are as their Diameters, the Power P will be to the Weight W, as the Diameter of the Axis X, to the Diameter of the Wheel AB, or (if Spokes be added) to the Distance of the Extremities of any two opposite Spokes, as D, E.

D 2

V. The

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B. It is a right Line, supposed to be drawn towards the Place where the moving Body tends:

V. The SCREW, *Fig. VIII. on Plate I, fronting p. 25.*

The Screw is used for *Pressure*, and sometimes for raising Weights.

Let AB be the Male Screw, DE the Nut or Female Screw, which is forced round by a Power applied to the Letter P, which is fixed thereinto. Now it is evident, that when the Lever P is turned once round, the Nut will be raised thro' a Space equal to the perpendicular Distance between two contiguous Threads of the Screw; wherefore the Power will be to the Force of this Machine, as the Distance between two Threads of the Screw is to the Spiral Circumference passed thro' by the Power.

VI. The WEDGE, *Fig. IX. on Plate I, fronting p. 25.*

Let ABD be the triangular Face of the Wedge, and suppose it were driven into a Piece of Wood quite to the Top AB; it is plain the Wedge will have passed thro' the perpendicular Space CD, while the Wood hath passed thro' the horizontal Space CB or CA on each Side. And therefore it is inferred, that the Power is to the Resistance to be overcome on each Side the Wedge, as the Thickness of half the Wedge CB to its Height CD. But there are various Proportions stated by different Authors concerning this Matter, as appears from the Authors quoted in *Johnson's Quaestiones Philos.* Page 69, 70. And they who would see them all well accounted for, may consult *Rowning's Comp. System of Philos.* Part I. Chap. 10. Page 72, 73.

These, with the *Inclined Plane*, are all the simple Mechanical Powers, of which all others, how complicated soever, do consist.

Hence the greatest Artifice in *Mechanics* is to contrive the Machine, so that the Power may have the greatest Degree of Velocity, and the Weight to be raised the least Degree possible.

From hence also it is plain, that what is gained in Power is lost in Time; and that, since the Force of the Power arises from the Product of the Celerity into the Quantity of Matter, tho' the Quantity of Matter be infinitely diminished, yet it shall effect as much as before, by means of a greater Celerity.

Suppose a Man can press with the Force of 200 Pounds, and that the Weight of the Earth be 399784700118074464789750; now imagine the Earth placed at one End of a Lever, at the Distance of 6000 Miles from the Prop or Center of Motion;

then



tends : As *ab* is the Direction of the Body A, in *Fig. VI. of Plate IV*, fronting *p. 70*.

A. What other Divisions of Motion do you make ?

B. According to the Force impressed on Bodies, their Motion is either *simple* or *compound*.

A. Pray, Sir, what is *simple Motion* ?

B. When only one Force or Power acts on any Body, the Motion produced thereby is simple, and according to the Direction of the impressed Force.

A. And, next, please to explain *compound Motion*.

B. This is produced when two or more Forces act on any Body in different Directions: Thus, suppose a Power H acts on the Body A, with eight Degrees of Force, in the Direction AB; and another Power I acts on it, with six Degrees of Force, in the Direction AC; I say, the Motion of A is not simply in either of the Directions AB or AC, but in a Direction compounded of both, *viz.* AD, and that with ten Degrees of Force, and arrives to D in the same Time as it would have ar-

then must the Person or Power be applied at the Distance of 11993541003542233943692500 Miles to sustain it. If the Earth be raised but one Mile, the Power must move through the Space of 1998923500590322323948 $\frac{3}{4}$  Miles. The Distance of Saturn from the Sun (equal to its mean Distance from the Earth) suppose 770310000 Miles, by which divide the Number 11993541003542233943692500, the Quotient is 15569745951035731, which is so many Times Saturn's Distance from the Earth, that the Person must be placed from the *Fulcrum* to sustain the Earth.

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rived to B or C with those Forces singly. See Fig. VIII. \* of Plate IV, fronting p. 70.

C H A P.

\* 1. For since the Body A is urged by a Force represented by the Line  $AB = 8$ , and by another represented by  $AC = 6$ , the Line AC may be conceived to move parallelly along the Line AB, while the Line AB, in like Manner, and in the same Time, moves thro' the Line AC; and the Body A being necessarily found in both these Lines, it must be in that Point where they intersect each other; therefore drawing BD parallel to AC, and CD parallel to AB, these Lines BD and CD will be the Directions of the Forces for the given Time, and consequently the Point of their Intersection D, will be that in which the Body A will be then found; and the Line AD, the Path described by the Body A, or the Point D, in the several Moments of that Time.

2. Hence it is easy to conceive how any given *simple* Motion, as AD, may be resolved into two other simple Motions, AB and AC, whose joint Efficacy is equivalent to that of AD; and hence any Motion may be considered as *simple* or *compound*; on which Principle the Doctrine of the *Composition* and *Resolution* of Motion, or Forces, depends.

3. Let FG (Fig. X. of Plate I, fronting p. 25.) be the Section of a Plane, on which a Body impinges in the oblique Direction AD; then is the Force with which it strikes the Plane in D, represented by AD, which is resolvable into the two Forces AC and CD, of which AC being parallel to the Plane FG, does not affect it in the least; but CD being perpendicular thereto, expresses all the Force with which the Body A strikes the Plane in the Direction AD. But CD is equal to AB, which is the Sine of the Angle of Obliquity ADB, and had the Body A impinged perpendicularly on the Point D, its Force had been expressed by ED; but ED is equal to AD: Therefore the Force of a direct Stroke is to that of an oblique one, as AD to AB; that is, as *Radius* to the *Sine* of the Angle of the Obliquity, or Incidence.

4. Suppose A to be a Particle of Water, Air, &c. then since all Surfaces are as the Squares of their like Sides, it is evident that several Quantities of *Water*, *Wind*, &c. which fall in various oblique Directions on the *Float-boards* of a *Wheel*, the *Rudder* of a *Ship*, the *Sails* of a *Mill* or *Ship*, &c. will have their several Forces as the Squares of the Sines of their several Angles of Incidence; and therefore are easily computable. See Harris's *Lex. Tech.* under the Word *Sail*. Motte's Mechanical Powers.

## C H A P. VI.

## Of LIGHT.

B. **H**AVING thus taken a brief Survey of the most general and essential Properties of Matter, let us now proceed to those which are more particular, called the specific or accidental Qualities of Bodies.

A. Why are they called *specific* or *accidental*?

B. They are called *specific*, because thereby the several Kinds of Bodies have their Division into various Species, and are what they are, being thus differenced from one another: Thus, *Fire* by *Heat*, *Glass* by *Transparency*, *Liquors* by *Fluidity*, *Solids* by their *Fixity*, &c. are different from each other; and are accounted particular *Species* of Matter.

5. On this Principle may we calculate the Ratio of the Power and Weight sustaining each other in *Equilibrio* on an *Inclined Plane*. Let the Plane be AF (*Fig. XI. of Plate I, fronting p. 25.*) on which the Weight W is sustained by the Power P, the Angle of Inclination is AFG. The Weight touching the Plane in the Point B, thro' the Center E, perpendicular to the Plane, draw ED; and perpendicular to the Horizon FG draw BC, parallel to which draw DH; then will BD express the Force whereby the Weight gravitates on the Plane, DH the Force whereby it gravitates towards the Earth, and BH the Force whereby it is attracted by the Power P, as being parallel to AE. But BH is to HD (as CD is to BD) as AG is to AF; that is, the Power P is to the Weight W, as the Height of the Plane AG is to the Length AF; or, as the Sine of the Inclination to Radius.

D 4

A. But



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*A.* But you do not say why they are termed *accidental*?

*B.* I was just going to tell you, they are thus called, because they are not *essential* to Matter, but happen to be a Part thereof *per Accidens*, or by Accident; for it is purely so, that one Part of Matter is disposed to be *hot*, another *cold*, another *dry*, another *light*, another of this Colour, and another of that \*.

*A.* Which of those Qualities will you begin withal?

*B.* LIGHT †; this being the most considerable and wonderful of all others; and by which all Things are made visible and known.

*A.* Pray what do you call *Light*?

*B.* That Quality of certain Bodies, whereby they become visible to us, and render others so.

*A.* What is the true Cause of *Light* in those Bodies?

*B.* No Man can certainly tell; however, some affirm it to consist in the extreme vibrating Motions of the Parts of those luminous Bodies.

*A.* By

\* What is here said is in regard only of the Particles of Matter in themselves considered; for no doubt the all-wise Creator had *perfect Designs* and *Ends* in View, in his Choice and Distribution of the *Qualities* of natural Bodies; and which we must therefore look upon as a great Basis of the Doctrine of *final Causes*.

† *Aristotle* defines Light to be *ἐνέργεια τῆ διαφανῆς*, the internal Action or *Energy* of pellucid Bodies. This favours too much of an Hypothesis.

*Des Cartes*, and his Followers, distinguish two Kinds of Light: (1.) *Primigenial*; which, they say, consists in a certain Motion of

## 57

A. By what Means doth *Light* come to affect our Eyes?

B. It is supposed this is owing to a very fine ætherial Matter, vastly rarer and finer than Air, which is the *Medium* by which the Rays of those luminous Particles are transmitted or propagated to our Eyes, and illuminate them with their *Light*.

A. You then suppose, I find, that what we call Rays of *Light* are real Bodies, or Particles of Matter, endued with the Quality of *Light*, and not the Quality itself †.

B. You hit it; I do indeed not only suppose it, but am sure of it.

*A.* Are you indeed ! then I am sure not only myself, but Thousands more, have been long

*the Particles of a lucid Body, which agitate and propel the subtile Matter in its Pores every Way, and in all Directions. (2.) Secondary, or derivative Light; which consists in an Endeavour to Motion, or an Inclination of that subtile Matter to recede from the Center of a lucid Body in straight Lines. Such are the curious Fictions of these hypothetical Philosophers.*

The *Newtonians* very justly make *Primigenial Light* to consist in a certain Motion of the Particles of luminous Bodies, which force out and off the said Bodies certain exceeding and inconceivably small Particles, which, with incredible Force, are every Way emitted in straight Lines: And derivative Light to consist not in an Endeavour to Motion, but in a real Motion of these Particles emitted from Bodies, as aforesaid. See *Clarke's Notes on Robault's Physicks*, Part I. Chap. xxvii. *Newton's Opticks* *Boerhaave's Chymistry*, with *Shaw's Notes*, Page 220, &c. *Boyle's Experiments* to make Fire and Flame ponderable. *Harris's Lexicon*, under the Word *Light*. *Hauksbee's Experiments*, and those of *Desaguliers*, *Gravesande*, &c. *Derham's Physico-Theology*, &c.

† Sir *Isaac Newton* computes the Force of Attraction in the small Particles of the Rays of Light to be 1000000000000000 Times greater than the Gravity of Bodies on the Surface of the Earth, according to the Quantity of Matter which is in them.

mistaken. Pray is not the Sun the Fountain of *Light* originally ?

B. No : He is only the greatest Body that emits *Light* in our *planetary System* : *Light* itself being a Quality innate to those Bodies which emit it naturally.

A. But why do you say naturally ?

B. Because *opaque* or dark Bodies, when heated beyond a certain Degree, will emit *Light* ; and all Bodies, especially sulphureous ones, having their Parts sufficiently agitated, do shine or emit *Light* : Whether this be by Percussion, as *Quicksilver*, when shaken in *Vacuo* ; or by Attrition, as a *Cat's Back*, or *Horse's Body*, &c. rubbed in the Dark ; or by Putrefaction, as happens in *Wood*, *Flesh*, &c. when putrefied ; or by any other Way.

A. Is the Motion of *Light* instantaneous or successive ?

B. It being found (by Observation) that *Light* is successive, or propagated in Time, hath at length ended this long and difficult Controversy.

A. By what Kind of Observations is this discovered ?

B. Astronomical Observations ; the principal of which is, that of the *Eclipses* of the *Satellites* of *Jupiter* ; for those *Eclipses*, when the Earth is between the *Sun* and *Jupiter*, happen seven or eight Minutes too soon ; and when the Earth is beyond the *Sun*, they happen as much later than they should by the *Tables* ; the Reason of which is, that *Light* hath



hath farther to go in the latter Case than in the former, by the Diameter of the Earth's annual Orbit \*.

A. Why, if this be the Case, you may nearly compute the Motion of *Light*; can you not?

B. Yes, easily; for since the Distance of the Sun from the Earth is known to be about 81 Millions of Miles, if that Number, viz. 81000000, be divided by 450, the Seconds in  $7\frac{1}{2}$  Minutes, the Quotient will be 180000 Miles; and so far doth Light fly every Second of Time.

A. Pray make this incredible Swiftnefs of *Light* a little more intelligible by Example.

B. I will. It is found that a Bullet, at its first Discharge from the Muzzle of a Cannon, flies one Mile in a little above  $8\frac{1}{2}$  Seconds, and therefore would be  $32\frac{1}{2}$  Years in arriving to the Sun; hence the Proportion of Swiftnefs in a Cannon-Ball and *Light*, is as 1 to 1530000 nearly; that is, *Light* flies one million five

\* To illustrate this important Discovery, let ADEB be the Earth's Annual Orb (Fig. XII. of Plate I, fronting p. 25.) C the Sun, I the Planet *Jupiter* in his Orb HK, and S a Satellite just entering his Shadow. Let D and E be two Situations of the Earth in its Orb, whose Distance DE is equal to the Semi-diameter of the Orb AC. Now it is plain, that if the Motion of Light were *instantaneous*, the Satellite S would appear to enter the Shadow at the same Moment to a Spectator in E, as to another in D; but, by many Years Observations, it has been found, that the Immerfion of the Satellite into the Shadow is seen at D about  $7\frac{1}{2}$  Minutes sooner than at E, which is 81000000 Miles more distant; and consequently, as Mr. *Romer* first observed, the Motion of Light is thereby proved to be *progressive*, and not *instantaneous*, as was formerly believed.

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hundred and thirty thousand Times faster than a Bullet at its first Discharge \*.

*A.* Wonderful are the Works of God ! Not only past finding out, but past Belief, when but imperfectly known ! But, pray, what other Properties of *Light* are discovered ?

*B.* *Light* is not only found to be a Body, but it is also found to consist of Rays tinged with all the original Colours in Nature.

*A.* In what Order are the Rays of *Light* found to be coloured ?

*B.* According to the different Degrees of Refrangibility in the Rays : From Rays less refrangible, to those that are most so, the Colours appear in this Order, *viz.* *Red, Orange, Yellow, Green, Blue, Indigo, deep Violet.* But more of Colours, when we discourse directly thereof by and by.

*A.* Pray, what other Affections of *Light* are observable ?

*B.* Its Reflexibility and Refrangibility †.

*A.* What

\* See *Derham's Physico-Theology, Book I. Chap. 4. Note 4th and 5th.*

† The *Reflexibility* and *Refrangibility* of *Light* make the Subjects of *Catoptrics* and *Dioptrics*, which are the two great Parts of the most curious and delightful Science of *Optics*. See Notes † and ‡ in Page 26.

I. OF CATOPTRICS.

1. *Catoptrics* is the Science of *Reflex Vision*, or that which is performed by Rays of *Light* reflected from the polished Surfaces of Mirrours of every Sort ; of which there are three very considerable, *viz.*

2. *Plane*

A. What do you call the Reflexibility of Light ?

B. The

2. *Plane Mirrours*, or Looking-Glasses, the chief Properties of which I have taken Notice of in the Text above, *viz.* that all Objects are represented in their *Images* just as far behind the Mirrour as they are really before it; that they appear situated on the same Line; and lastly, that the *Images* are in all Respects alike and equal to the *Objects* in Magnitude.

3. *Convex Mirrours*, or such whose Surface is *spherically* round, as MR (*Fig. XIII.* of Plate I, fronting *p. 25*;) to understand the Nature of which, let AB be an Object, from the Extremities of which A and B, let two Rays BD and AD fall upon the Mirrour in the Points C and D; let PC and QD be perpendicular to the Convex Surface in the said Points C and D; then make the Angle PCE equal to the Angle BCP, and CE shall be the Ray BC reflected; in like manner, the Angle QDF being made equal to the Angle ADQ, the Ray DF shall be AD reflected. Now it is evident the Object AB will be seen by an Eye at EF in the Direction of the reflected Rays EC and FD; that is, in the *Focus* of the Mirrour GH, which will be the *Image* of the Object AB.

4. By these Mirrours, (1.) all Objects appear *behind* the Glafs. (2.) Their Images are all *erect*. (3.) The Images are all less than the Object. (4.) *Parallel Rays*, or such as come from Objects at a vast Distance, have their *Focus* or Image at the Distance of half the Radius of the Convexity. (5.) *Diverging Rays*, or such as come from near and small Objects, are represented nearer the Glafs than half the Radius. (6.) If the Distance of the Object be equal to the Radius of Convexity, the Image will be painted at  $\frac{1}{2}$  of the Radius behind the Glafs. (7.) In *converging Rays*, if the Distance of the Object be less than half the Radius of Convexity, the *Focus*, or Place of the Image, will be before the Glafs; otherwise always behind it. (8.) If the Object be a *Right Line*, the Image will be a *Curve*; if the Object be a *Plane* Superficies, it will be represented a *curved* one.

5. *Concave Mirrours* are such as are spherically hollow on the polished Surface, or that next the Eye. To understand the Properties thereof, let AB (*Fig. XIV.* of Plate I, fronting *p. 25*.) be an Object, BC and AD two Rays from the Extremities thereof falling on the Surface of the Concave Mirrour MR in the Points C and D; they will be reflected thereby into the Rays CE and DF, in the Direction of which the Image of the Object will be seen.

6. Whence



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B. The Disposition of the Rays to be reflected, or turned back from the Surface of any

6. Whence it is plain, (1.) that Rays falling on such a Mirrour, are by Reflection made to converge or intersect each other, as here in the Point *o*. (2.) The Object *AB* will appear inverted and diminished in its Image *ab*, in that focal Point *o*, to an Eye placed farther distant from the Glafs, at *EF*. (3.) If the Eye be placed nearer the Glafs, than the *Focus o*, the Image of the Object *AB* will appear behind the Mirrour, and very much enlarged, as *GH*. (4.) *Diverging* Rays falling on this Mirrour, if the Distance of the Object be less than half the Radius of the Concavity, the Image will be behind the Glafs; if greater, before it. (5.) *Converging* Rays form the Image *always before* the Glafs. (6.) *Parallel* Rays are converged to a Point at the Distance of half the Radius before the Glafs.

7. From this last-mentioned Property of a concave Mirrour, it is easy to understand how they become *Burning-glasses*; for the Rays of the Sun being *parallel*, as coming from a vastly distant Object, all of them which fall on the Surface of the Mirrour are collected into a very small Space or Circle, whereof the Heat will be to that of the Rays uncollected, as the Square of the Width of the Mirrour to the Square of the Diameter of the Circular Spot, or as the Area of the Glafs to the Area of the Spot. The Heat then being thus prodigiously augmented, will burn violently in that Point; which is the Reason why it is called the *Focus*.

## II. OF DIOPTRICS.

1. This Part of Optics considers the Nature of Vision by Rays of Light refracted through different *Mediums*, but principally through *Glasses* in those Forms we call *Lenses*.

2. Of *Lenses* there are five principal Sorts, *viz.* (1.) A *Plano-convex*, marked *A*, (*Fig. XV.* of Plate I, fronting *p. 25.*) which has one *plane* Surface, the other a *convex* one. (2.) A *Double-convex*, as *B*, which has both Surfaces *convex*. (3.) A *Plano-concave*, as *C*, which hath one *plane*, the other a *concave* Surface. (4.) A *Double-concave*, as *D*, which has both Surfaces *concave*. (5.) A *Convex-concave*, as *E*; one of whose Sides is *convex*, and the other *concave*. This *Lens* is usually called a *Meniscus*. The Line *FG* is the Axis common to each of those *Lenses*, as passing through their middle or *vertical* Point.

3. Let *LN* be a *double-convex* *Lens* in *Fig. XVI.* of Plate III, fronting *p. 62*; or a *double-concave*, as *Fig. XVII.* of Plate III, fronting *p. 62*. *AV* and *BU* the *Radii* of their *Convexities* and

Fig. XVII.  
Page 62.

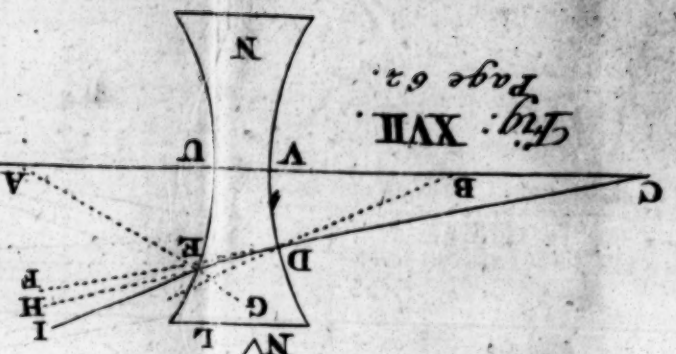


Fig. XVI.  
Page 62.

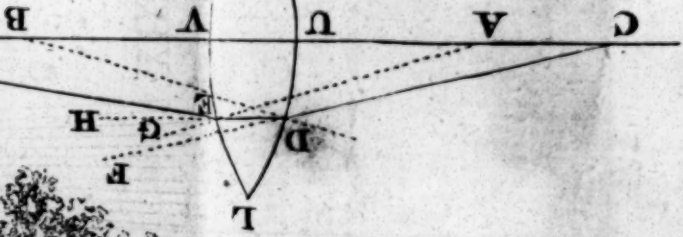


Fig. XXI.  
Page 65.

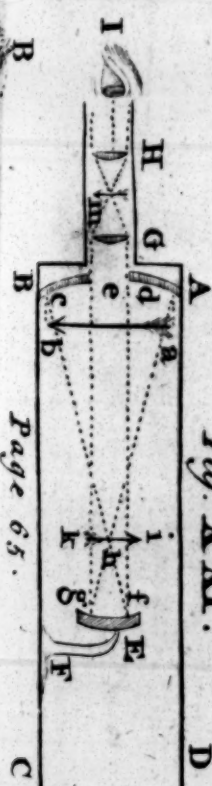


Fig. XXII.  
Page 67.

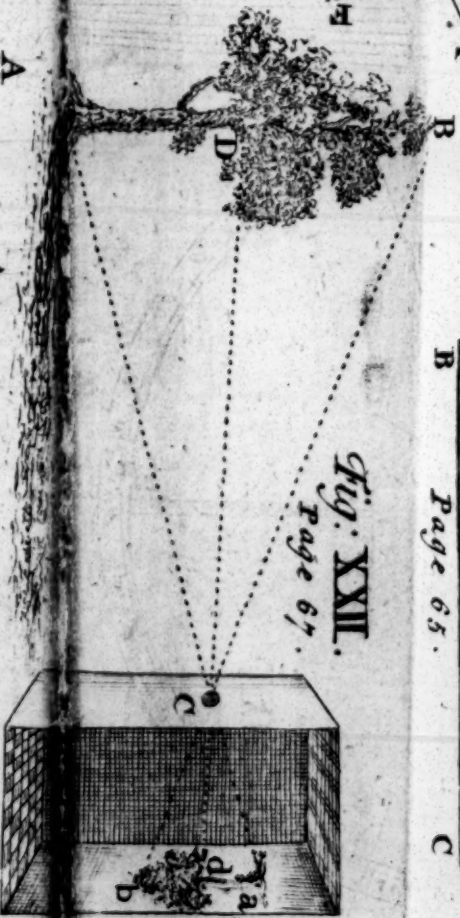


Fig. XXIII.  
Page 67.

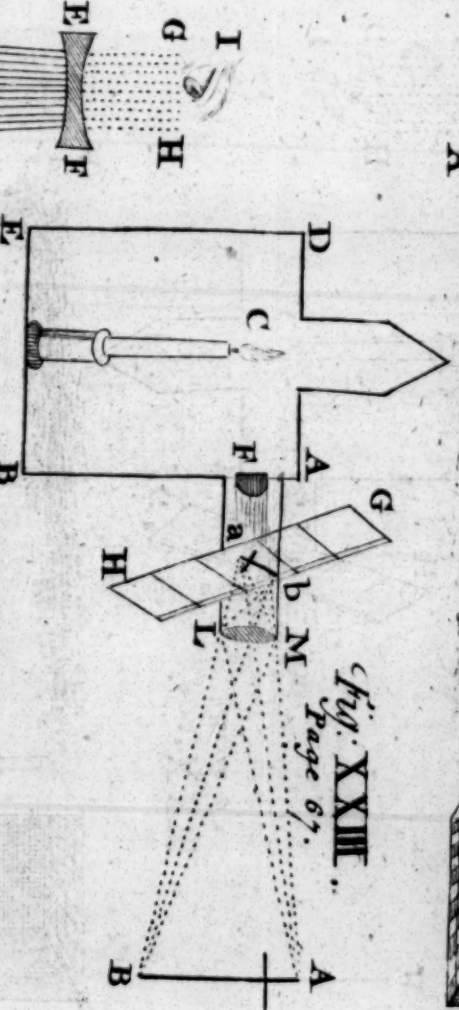


Fig. XVIII.  
Page 63.

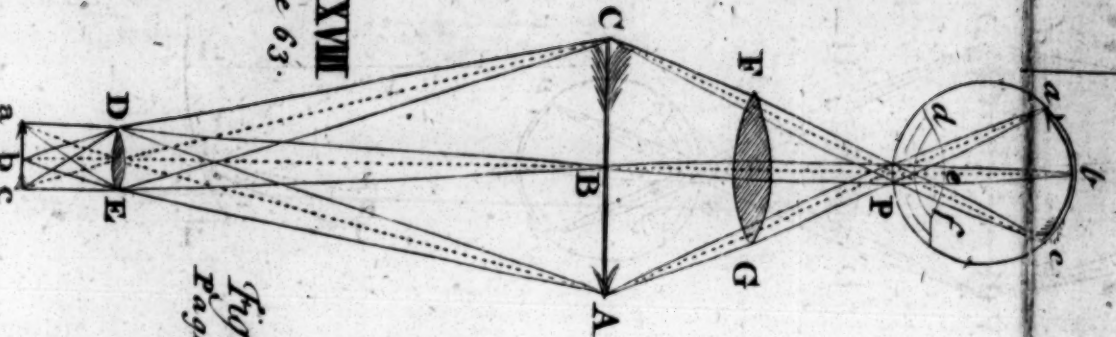


Fig. XIX.  
Page 64.

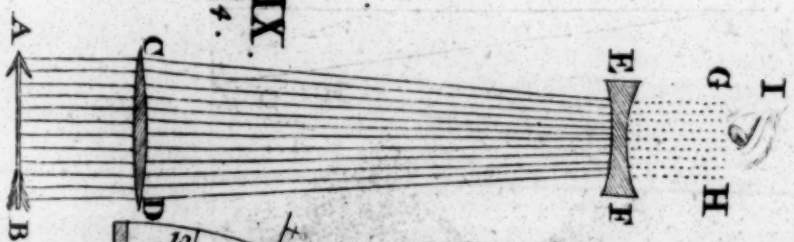
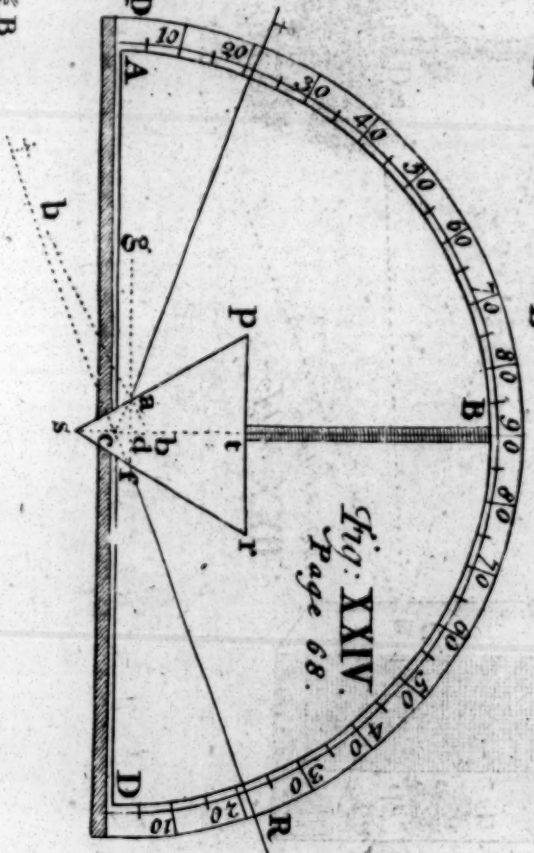


Fig. XXIV.  
Page 68.









any Bodies on which they fall : Thus the Ray  
aB

and Concavities, which are here equal ; from any Point C in the Axis, suppose a Ray CD proceed *diverging*, and fall on the Surface of the Lens at D, to the Point D draw BD perpendicular, then the Ray passing through the denser Substance of Glass will be bent out of its course CE towards the Perpendicular DB, and so be refracted from D to E on the other Surface ; draw the Perpendicular AG through the Point E, then the Ray DE passing out of *Glass* into *Air*, will be refracted from its second Course DH, into a third Course EI from the Perpendicular EG or AE. Now it is evident from the Schemes, that the Ray EI is, by the *Convex* Lens, made to converge towards the Axis, and to intersect it in I ; but in the *Concave* Lens, the same Ray E is made to converge from the Axis. And this would have been the Case of a *Plano-convex*, and a *Plano-concave* Lens, with little Variation.

4. Concerning the various Properties of all Varieties of Lenses, and Rays incident upon them, see Mr. *Molineux's* Optics, Dr. *Gregory's* Elements of Catoptrics and Dioptrics, with Dr. *Brown's* Supplement thereto, and Mr. *Rowning's* Comp. System of Philosophy, Part III. All which may be seen confirmed by Experiments in *Gravesande's* Math. Elements of Natural Philos. Vol. II. Book III. Part II.

What is here observed of the Nature of Lenses in general, is sufficient for understanding the Structure and Effects of dioptric Machines ; as the *Microscope*, *Telescope*, *Camera Obscura*, and *Magic Lanthorn*.

### III. Of the MICROSCOPE.

1. Let DE be the Object-Glass, and FG the Eye-Glass of a Microscope ; *Fig. XVIII.* of Plate III, fronting *p. 62* ; *abc* a small Object to be viewed by the Eye at P. Draw the dotted Line or Axis *aA* through the Center of the Lens DE, and let AD be a Ray proceeding from the extreme Point *a* of the Object, and incident on the outmost Part D of the Lens ; this will be refracted into the Direction DA, and intersect the Axis in the focal Point A. In like Manner a Ray *aE*, incident on the other Side E, will be refracted into EA, meeting the Axis in the same Point A. So that the whole Cone of Rays *DaE* will be refracted into the Cone DAE ; and therefore the Extremity *a* will be represented at A. In the same Manner the Cones *DbE* and *DcE* will, after Refraction, become DBE and DCE ; consequently, the three Points *a, b, c*, will  
be

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*aB* falling on the Surface *AC*, in the Point *B*,  
is

be represented in the Image at *A*, *B*, *C* ; and all Points between the former will be painted similarly between the latter.

2. Therefore the small Object *abc* will have its Image formed in the Focus *ABC* ; and the Image will be in Proportion larger than the Object, as the Distance of the Image is greater than the Distance of the Object from the Glass *DE*. Also the Position of the Object will be inverted in its Image, as is evident from the Figure.

3. The Image *ABC* is now to be considered as an Object viewed through the Eye-Glass *FG*. Now it is to be *well noted*, that Rays falling parallel on equally convex Lenses are collected together in the Center of Convexity ; therefore if the Image *ABC* be placed in the Center or *Focus* of the Eye-Glass *FG*, all the Rays coming from it, after Refraction through the Glass, will proceed parallel till they arrive at the Pupil of the Eye at *P* ; and that they should do thus, is necessary to cause distinct Vision.

4. In the Pupil *P*, the Rays all cross each other again, and by the *crystalline Humor* (*def*) are collected or united in the Focus, which is on the Retina in the Bottom of the Eye, and there the second Image *abc* is formed in its true Position, like that of the Object *abc*. Yet, notwithstanding this, the Mind conceives the Idea of the Object as inverted, the Reason of which odd *Phænomenon* I shall not here enquire, but proceed to the Construction

### IV. OF TELESCOPES.

1. The first Telescope I shall consider is that called a *Prospective-Glass*, (*Fig. XIX.* of Plate III, fronting *p.* 62.) consisting of a *Convex Object-Glass* *CD*, and a *Concave Eye-Glass* *EF*, which is to be so placed, that the *Focus*, or Center of each Lens, may fall on the same Point, or coincide ; then shall parallel Rays coming from any Object *AB*, and refracted by *CD* towards *EF*, by passing through *EF*, be again made *parallel*, and consequently fit to produce distinct Vision. (1.) This Glass shews Objects *erect* ; for the Rays do not cross or intersect each other any where, which alone causes Objects to appear inverted. (2.) It *magnifies* Objects in the Proportion of the *focal* Distance of the *convex* Lens *D*, to the *focal* Distance of the *concave* one *EF*. (3.) In this Glass no more of the Object is seen at one View, than what falls on the Pupil of the Eye *I*, which therefore is  
near

is reflected or turned back again in the Direction Bd. See Fig. IX. of Plate IV, fronting p. 70.

A. In

near; and large Objects is but a very *small Part*, and so this Glas is in such Cases but of *little Use*.

2. A second Sort of Telescope is that consisting of two Lenses also, but both *convex* ones, as AH and BI (Fig. XX. of Plate III, fronting p. 62.) Let K be the *Focus* of both Lenses, then will the Image of a vastly distant Object EF be there formed and appear inverted to an Eye placed in the Axis, MG any where behind the *Lens* BL. On this Account it is seldom used, unless to view the Heavenly Bodies, whose Position is not regarded. This Glas also magnifies Objects in Proportion of the Focal Distance of the Object-Lens QK to the Focal Distance of the Eye-Glas KL. In this Telescope, so much of the Object is seen at one View as falls on the whole Surface of the Object-Glas.

3. The third Sort of Telescope is that in common Use for viewing Land-Objects; and consists of one Object Glas AH (Fig. XX. as above) and three Eye-Glasses, all of the same *Focus*, as B, C, D. Hence it is plain this is the same with the foregoing Telescope, only with the Addition of the two Eye-Glasses C and D; for whereas the Object was before *inverted* in the Focus K, by adding the Glas C, it will be again made *erect* in its Focus O, and will so appear to an Eye I, placed behind the third Glas D, if the Focus both of C and D be made to fall on the same Point O. This Telescope then shews Objects *erect*, and is in other Respects the same as the last foregoing. See Note \*, in Page 22.

4. The fourth Sort of Telescope is that lately invented by Sir Isaac Newton, called the *Reflecting* or *Catadioptric* Telescope. This consists of a Tube ABCD, two, three, or four Feet long (Fig. XXI. of Plate III, fronting p. 62.) which is open at the End towards the Object CD, and at the other End is placed a concave Metalline Mirrour, as AB, perforated through the Middle at *e*; at a proper Distance is placed another small concave Mirrour E (in the Axis of the Tube) which is supported by the Stem or Foot F. The two Mirrours are so disposed, that the Focus of each may fall on the common Point *b* between them; then the Image of any Object entering the Tube, as *ab*, and falling on the large Mirrour AB in the Point *dc*, is from thence reflected between the Rays *db* and *cb* to the Focus *b*, where the Rays crossing, invert the Image, as at *ik*; and this Image being now also in the Focus of the Mirrour E, after falling thereon in the Points

E

f, g,



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*A.* In what Manner or Order is this ?

*B.* The

*f, g*, it will be reflected from thence back again in *parallel Rays*, which pass through the Hole *e* of the great Mirrour, and falling on a Convex Lens at *G*, do again cross each other in its Focus *m*, and there represent the Image *erect* to be viewed by an Eye *I*, through the Eye-Glass *H*, whose Focus is also in *m*.

5. This Telescope magnifies the Diameters of Objects in the Proportion of the *Focal Distance* of the *Object Mirrours* to the *Focal Distance* of the Eye-Glass, as do the other Telescopes; but in this, by Reason of the Reflection of Rays, an Eye-Glass with a much shorter Focus may be used, than in the common ones by Refraction; and therefore a *Reflecting Telescope* of six Feet in Length will magnify an Object as much, as a *Refracting* one 100 Feet long; on which Account they are now in much Esteem, though there be many Difficulties in them also.

6. If the Focal Distance of the Object-Glass or Mirrour (in any Telescope) be 50 Inches, and that of the Eye-Glass one Inch; then will the *Diameter* of a distant Object be magnified 50 Times; the Surface 2500 Times; and the Solidity of the whole Body 125000 Times.

### V. Of the CAMERA OBSCURA.

1. The *Camera Obscura*, or Dark Chamber, is nothing but a Chamber, Room, or Box darkened, and a Convex Lens fixed in a Hole made in one Side thereof, as at *C* (*Fig. XXII. of Plate III, fronting p. 62.*) through this Lens any Object before it without, as *AB*, a Tree for Instance, will have its Image carried through the Lens between the Rays *AC* and *BC*; which proceed to the other Side of the Room (supposed to be at the Focal Distance of the Lens *C*) where they paint the Image of the Object in the most lively Colours, far beyond the Imitation of the best conducted Pencil, in regard of Colouring, and with respect to the *Motion* of every Part moved in the Object; this is allowed such an inimitable Perfection, as is peculiar to *Nature's Painting* only. Indeed the Image *ab* is *inverted*, and is in Proportion to the Object, as its Distance *Cd* from the Glass to the Distance *DC* of the Object.

2. If the Object be placed at the Distance of twice the Radius of the Convexity of the Lens, the Image shall be exactly as big as the Object. Note, I here suppose the Lens *C* to be *doubly* and *equally* Convex. The only Time for making a dark Chamber, is when the Sun shines; for unless the Objects are strongly enlightened, the Picture will be obscure and little worth. The *Sky Optic Ball*, with its Glasses, is most commonly and conveniently used for this Purpose.

VI. The

B. The Law of Reflection of *Light* is invariable; for the Angle  $aBc$ , of the incident Ray  $aB$ , is ever equal to the Angle  $cBd$ , of the reflected Ray  $Bd$ , and the Perpendicular  $cB$ . See *Fig. IX. of Plate IV*, fronting *p. 70*.

A. What do you mean by the Refrangibility of *Light*?

B. The Disposition of the Rays of *Light* to be refracted, or broken out of their direct Course, in passing through one transparent Body or *Medium* into another: Thus the Ray  $aB$ , passing through the Medium of Air to  $B$ , and there striking on the Surface of Water  $AC$ , is refracted or broken out of its direct Course  $BE$ , into another  $BF$ , towards the perpendicular  $BG$ . See *Fig. X. of Plate IV*, fronting *p. 70*.

A. Doth the Refrangibility of Rays also observe any stated Law or Order?

B. Yes: For the Line  $HI$ , of the Angle of Incident  $CBH$ , is always in the same Proportion to the Line  $MK = IK$ , of the Angle of Re-

## VI. The MAGIC LANTHORN.

After all that has been said in this Note, it is easy, from a bare Inspection of *Fig. XXIII. of Plate III*, fronting *p. 62*, to understand the Reason of the Effects of a *Magic Lanthorn*. Let  $ABDE$  be a Section thereof,  $C$  a Candle placed therein,  $F$  a large Convex or Hemispheric Lens, which strongly illuminates the inverted Pictures in the Plate  $GH$ ; the Light coming from any one of these, as  $ab$ , is, in passing through the Lens  $LM$ , made to spread and diverge very much, and consequently to paint a very large Image  $AB$  on the Wall, or any Thing in the Focus of those Rays. If this Image be a *Ghost*, the *Devil*, &c. it appears very terrible and surprising to the Spectators who are unacquainted with the Nature of *dioptric Machines*.

fraction GBF; as 4 to 3 in *Water*; and as 17 to 11 in *Glass*. See *Fig. X. of Plate IV*, fronting *p. 70* \*.

*A.* What may we learn by this Doctrine of the Reflection of *Light*?

*B.* The Reason why Objects appear just as far behind any *Plane Speculum*, or *Looking-Glass*, as they really are before it, and the same Way: Thus, suppose AC the Section of a *Looking-Glass*, it is plain any Object placed before it at *a*, as the *Arrow*, will appear just so far behind the *Glass* AB as E, and directed to the same

\* The Proof of this Experiment is easy, and may be as follows. Let ABD be a Semicircle (*Fig. XXIV. of Plate III*, fronting *p. 62.*) large and duly graduated; C the Center thereof, before which is to be placed a Prism of Glass, represented by *prs*, the upper Plane or Side of which *pr* must be fixed parallel to the Horizon, or to AD. Suppose the Angle of the Prism *psr* be 60 Degrees, then will the Angle *pst* be 30. Let *Ic* be a Ray incident on the Prism in the Point *a*; if this Incidence be such, that the Ray entering the *Medium* of Glass be refracted into the Direction *af*, parallel to the Horizon AD, it shall emerge out of the Glass into the Air in the Direction CR, making the Angle RCD equal to the Angle ICA. Now in order to find this Angle, draw through *a* the Line *bb* perpendicular to the Side of the Prism *pr*, and also *gd* parallel to the Horizon AD, then shall the Angle *bad* be the Angle of Refraction in the Prism as required, which is known, as being equal to the Angle *pst*, or 30 Degrees; therefore, if the Ratio of the Sine of Incidence be to that of Refraction as 17 to 11, out of Air into Glass, it will be, as 11 is to 17, so is the Sine of *bad* = 30° to the Sine of Incidence *Iab* = 50° 45', nearly; from which take *gab* = 30, there will remain *gal* equal to ICA = 20° 45'; and since any Object at I under the Angle 20° 45' does actually appear to an Eye at R under the same Angle, it proves the Truth of the said *Ratio*. And this always will be the Case, be the Angle of the Prism what it will.

If the Figure *prs* were an hollow Glass Prism, this filled with various Sorts of pellucid Liquors, would exactly shew the different refractive Powers of those Liquors. Also, a Piece of Looking-Glass placed horizontally at C, shews, that the Angle of Incidence ICA is equal to the Angle of Reflection RCD.

Point



Point in the *Glass* B: For all Objects appear in that *Ray* Ed, that meets the Eye in *d*, be it any how reflected or refracted. See *Fig. IX.* of *Plate IV*, fronting *p. 70.*

A. And are our Eyes thus deceived by the Refraction of *Light*?

B. Beyond your Imagination, I believe.

A. Aye, indeed! Pray oblige me with an Example how, and in what Respects?

B. I will; and that by a very vulgar Experiment: Suppose AGHB be a *Vessel*, whose Length GH is 56 Inches; let any Object, as a Half-Crown, be placed exactly in the Middle thereof at F; then let the *Vessel* be filled with Water to the Height CD, 24 Inches; let FP be a Ray of *Light* passing from the Object F to P, but there meeting with the Air, is refracted towards N, and becomes PN. Now it is evident, an Eye placed in N cannot, by any Means, see the Object F (for the Sight is interrupted by the Side of the *Vessel* at *e*) before the Water is poured into the *Vessel*; after it is poured in, the Eye at N will indeed see the Object F, yet not in its true Place at F, but in another, distant  $15\frac{3}{4}$  Inches, at E; also to an Eye placed perpendicular over the Object F, it will appear to be in O, and the whole Bottom of the *Vessel* will seem elevated to IK, the Height of FO, 11 Inches. See *Fig. XI.* of *Plate IV*, fronting *p. 70.*

A. Well, it is very wonderful, as well as diverting and improving, to see and consider of these Things: I could not, indeed, have thought that Things placed so far out of Sight

could thus be made visible; and that we should behold them in Places so far distant and different from the true: It is well we have Reason to guide us, for I perceive our most exquisite Senses are fallible, and often deceived.

*B.* It is true, our Senses are liable to Deception, and it is well for us in many Cases they are; for as I go on, I shall often shew you the Advantages which accrue to us thereby, and from the Causes thereof particularly the Reflection and Refraction of *Light*.

*A.* How came Bodies first of all to be endued with this wonderful Property of *Light*?

B. By the omnipotent *Fiat* of the great Creator; he said *יהי אור, Esto Lux*, let there be *Light*, and immediately there was *Light*; and the stupendous Body of the Sun was created, as it were, a *Repository* or *Store-House* thereof, whence it was to be distributed to every Part of the *Planetary System*, in order to make the Whole visible, and useful to the various Inhabitants thereof.

*A.* Can you give any Account of the Smallness of the Particles of *Light*?

B. Yes: It is computed, that in a Second of a Minute, there flies out of a burning Candle the following Number of Particles of *Light*,  
4186600000000000000000000000000000000000000,  
which is 10 000 000 000, or ten millions  
of millions Times a bigger Number than  
10000000000000000000000000000000000;  
the Number of the Grains of Sand computed  
to be contained in the whole Earth \*.

\* See the Calculation in *Nieuwenxtijt's* Relig. Philosopher.  
C H A P.



Page 70

Fig I. Page 37.



Fig III. Page 37.

Fig II. Page 39.

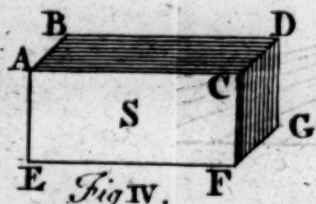


Fig IV. Page 37.

Plate IV.

Fig V. Page 39.

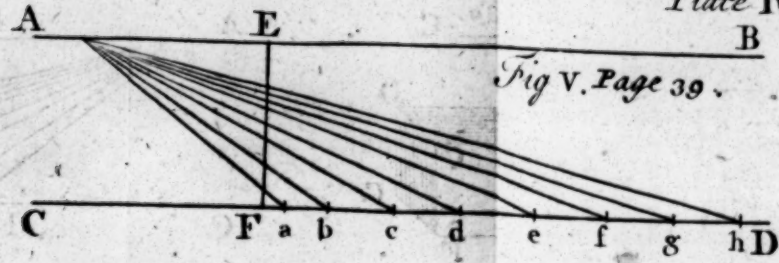


Fig VI. Page 40.

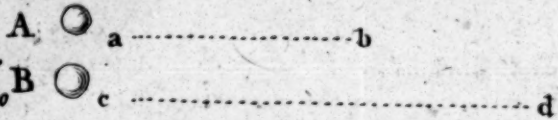


Fig VII. Page 40. 50.

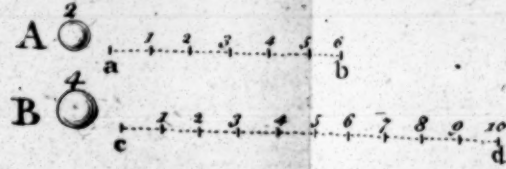


Fig VIII. Page 54.

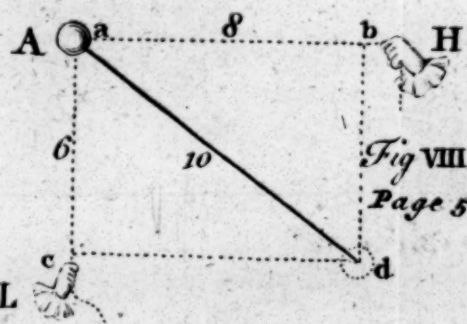


Fig IX. Page 65, 67, & 69.

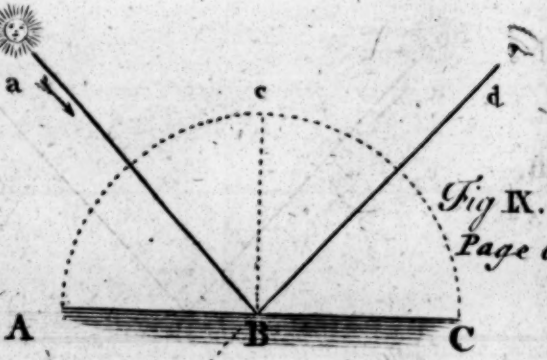


Fig X. Page 67 & 68.

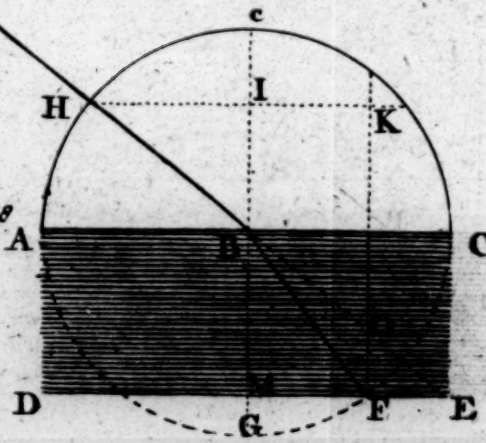
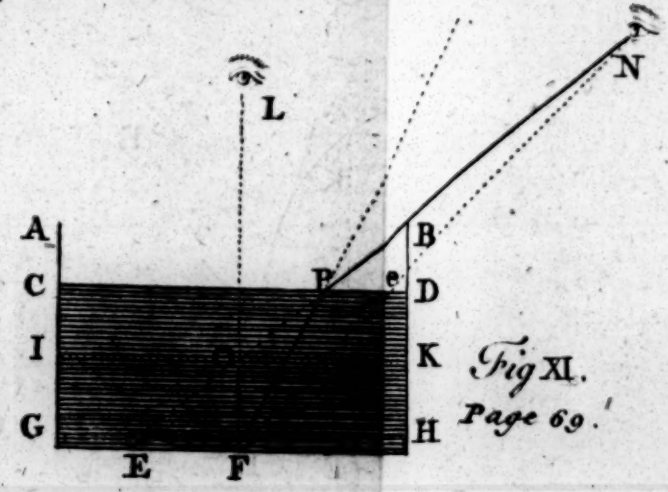


Fig XI. Page 69.



Em: Bowen Sculp.





## C H A P. VII.

*Of the COLOURS of LIGHT, and natural BODIES.*

A. **N**OW, if you please, *Sir*, let us turn our Discourse to the *Phænomena* of *Colour*: And first, be pleased to define what *Colour* is.

B. *Colour* is that which ariseth from a certain Quality of Bodies, whereby they are disposed so to modify and reflect the Light falling on them, and striking on the Organ of Sight, as thereby to occasion or produce the Sensation of *Colour* in our Minds: And that Sensation in us is also called *Colour*.

A. Whence is the Original of *Colours*?

B. All the *Colouring* in the Universe proceeds originally from the *Rays of Light*; for in them are contained all the primary, original, and absolutely pure and unmixed *Colours*\*.

A. Which,

\* *Des Cartes* pretended, that *Colours* resulted from the Relation of the direct and circular Motion of *Ethereal Globules*; if the Direct be slower than the other, *Red* is produced; if more rapid, *Violet*; and the others between these Extremes accordingly.

Dr. *Hooke* supposed they consisted in the Obliquity of the Pulses of the *Ethereal Matter*. *Malbranch* made them the Effect of Vibrations of Light, more or less quick. *Regnault* has a particular Hypothesis on this Head in his *Phil. Conversations*, Vol. II. Page 391, remarkable for nothing but Novelty, and the Presumption of the Author. The great *Barrow* imagined that Co-

*A.* Which, and how many, are those primary and original *Colours*?

*B.* Those which follow: 1. *Red*, 2. *Orange*, 3. *Yellow*, 4. *Green*, 5. *Blue*, 6. *Indigo*, 7. *Violet*.

*A.* How are those *Colours* discerned and distinguished in the *Rays of Light*?

*B.* By Means of the different Degrees of its Refrangibility; for those Rays which are least refrangible, are tinged with Red, and paint that *Colour* on Bodies; and those which are most refrangible, are Violet and Purple, and paint Bodies therewith; and the intermediate Degrees of refrangible Rays are dyed with the intermediate *Colours*, in the Order before mentioned \*.

*A.* By what Experiment do you prove this Doctrine?

*B.* By this easy one following: In a Chamber made dark, make an oblong Hole in the Window-Shutter at F, about  $\frac{1}{8}$  of an Inch in Breadth, through which will enter the Sun Beam FH; and a large Prism ABC, placed at about 20 Feet from the Hole, will refract the Rays of this Beam; after which they will again unite, and become a white Beam at H,

lours consisted in a constipated and rare Light. But Sir *Isaac Newton* has shewn the Errors of Hypotheses about Colours; and proves the Truth of his own new Doctrine by undeniable Experiments.

\* Light is supposed to be more or less *reflexible* or *refrangible*, as the Particles thereof are of a lesser or greater Magnitude; the Particles of *Red Light* being the greatest, and those of *Violet* the least, of all others; these, therefore, excite the least, and those the largest Vibrations in the *Optic Nerve*, which occasion different Sensations.

where



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where let be applied an opake Body GHI, at the Distance of two or three Feet from the Prism, in which let there be an oblong Hole made at H,  $\frac{1}{16}$  or  $\frac{1}{8}$  of an Inch in Breadth, through which the white Part of the Beam being transmitted, and made to fall on a Piece of white Paper placed after, will there paint the primitive original *Colours of Light*; suppose *Red* at *t*, *Yellow* at *s*, *Green* at *r*, *Blue* at *q*, and *Violet* at *P*. *Fig. XII. of Plate VIII, fronting p. 120.*

*A.* Very good; and what is the Consequence of all this?

*B.* Why then, with a Piece of Wire R, (or any opake Thing about  $\frac{1}{16}$  of an Inch thick) you may, by intercepting the Rays at *k, l, m, n, o*, take away any one of the *Colours* at *a, s, r, q*, or *P*, whilst the other *Colours* remain as before.

*A.* What do we learn by this Experiment?

*B. First*, That the *Rays of Light* paint natural Bodies with different *Colours*. *Secondly*, That the least refrangible Rays, as *t*, paint *Red*; and the most refrangible ones, as *P*, paint the deepest *Violet Purple*; and that other intermediate refrangible Rays paint the other intermediate *Colours*. *Thirdly*, That those Differences of *Colour* are absolutely and really existing in the *Rays of Light*, and do not arise from the different Confines of Shadow, variously modifying the *Light*, as has hitherto been the Opinion of Philosophers

*A.* I think it seems from hence, as if you would insinuate, that *Colours* are not connate with Bodies, or naturally in them, but painted on them by the *Rays of Light*?

*B.* It

B. It is very true; *Colours* only are in the *Rays of Light*, not in Bodies; and all Bodies are of the same Hue in the Dark, and appear differently coloured only by, and in the *Light*.

A. Strange Doctrine this! I am apt to think you'll persuade very few, that *Colours* are not in Bodies, when they constantly see all around them tinged with such an agreeable Variety.

B. If they will not be convinced by Reason and Experience, they must remain ignorant, and still possess their Prejudices and Errors.

A. But, according to this Notion of *Colours*, how comes it to pass, that some Bodies are all of one *Colour*, some all of another, and some of so many different *Colours*?

B. This is easily conceived; for the Matter of some Bodies universally reflects one Sort of Rays more copiously than another; and according to the Refrangibility of those Rays are the Bodies coloured: Thus *Minium* reflects the least refrangible Rays most copiously, and thence appears *Red*: *Violets* reflect the most refrangible Rays, and thence have their Colour; and so of their intermediate Degrees: Again, the Matter of some Bodies is such, as reflects different refrangible Rays; and therefore is in various Parts of various *Colours* \*.

A. Pray,

\* The Colours of natural Bodies are of two Sorts. (1.) *Variable*, which change and differ according to the Situation of the Eye, as in *Silks*, *Satins*, and the Tails of *Peacocks*, &c. (2.) *Permanent*, which are always the same, and never vary. To understand the Reason of both which, it is necessary to premise the following Things.

First,

8  
MC





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A. Pray, Sir, what can be the Meaning, that *White* and *Black* are not reckoned among the *primary Colours of Light*?

B. Because

*First*, That Rays of Light, by Means of a thin transparent Plate of *Air*, *Water*, or *Glass*, &c. are separated from one another; and according to the different Thickness of the Plate, the Rays of some Colours are transmitted, and those of others are reflected.

*Secondly*, Such a very thin Plate is of a different Colour when seen by the transmitted Rays, from that which it is tinged with when seen by reflected Rays.

*Thirdly*, To prove this, the usual Experiment is to take a Plano-convex Glass (whose convex Surface is the Segment of a very large Sphere) as A (*Fig. XXV. of Plate V, fronting p. 75.*) lay this with its convex Surface on a plain Piece of Glass B. and compressing them together, there will appear, in the Point where they touch, a dark central Spot, and about it various coloured Circles, as represented within CD.

*Fourthly*, The Glasses thus compressed being placed under a Microscope, the Colours of the several Circles may be clearly and largely viewed, and the Breadth of each, as also the Distances of those Circles, may be accurately measured (by a Micro-meter fitted to a Microscope) to the 10000th Part of an Inch.

*Fifthly*, To find the Thickness of the Plate of Air between the Glasses at the Periphery of any coloured Ring, say—As the Diameter of the Glass's Convexity is to the Semidiameter of any Ring, so is that Semidiameter to the Thickness of the Plate of Air at its Periphery. Suppose the Diameter of the Sphere, the Glass was ground to, was 12 Feet, or 144 Inches, and the Semidiameter of the Circle  $\frac{1}{16}$  of an Inch; then,  $144 : \frac{1}{16} :: \frac{1}{16} : \frac{1}{14400}$ , therefore the Thickness of the Plate where that Circle is formed is  $\frac{1}{14400}$  Part of an Inch.

*Sixthly*, The Colours of the Circles seen by the reflected Light, are much more vivid and distinct, than those seen by transmitted Light, which are faint and more dilute.

*Seventhly*, The Rings made by Reflection are differently coloured from those made by the Transmission of Light; *White*, in the latter Case, will be opposed to Black in the former; *Red* to *Blue*, *Yellow* to *Violet*, and *Green* to a Compound of *Red* and *Green*.

*Eighthly*, The more obliquely the Rings are viewed in either Case, the larger they appear by much; nor do they follow the simple Proportion of the Obliquity of the View; but as this increases, the Circles swell and dilate themselves much more.

*Ninthly*,



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B. Because *White* is so far from being a pure, simple, original *Colour*, that, on the contrary,

*Ninthly*, The farther the Circles are from the Center, the lesser and fainter their Colours appear; the fifth, or sixth, is the last which appears distinct; though I have observed a faint Skim of Circles to the Number of 11 or 12 in the light Air.

*Tenthly*, Water applied to the Edges of the Glass, is attracted between them, and filling all the Interstice, is made to constitute as thin a Plate of Water, as before there was of Air.

*Eleventhly*, The Water approaching the coloured Circles in the Plate of Air, does in a great Measure destroy the Brightness of the Colours, lessen the Number of the Rings, and contracts their Peripheries in the Proportion of 7 to 8, nearly.

*Twelfthly*, Bubbles blown up in Soap Water exhibit the like Appearance of coloured Rings, brighter towards the Top where the Bubble is thinner; but towards the Bottom, where the Water running down makes the Bubble thicker, the Rings and Colours gradually become more faint and obscure, till at last they quite disappear.

*Thirteenthly*, Thin Plates of *Muscovy* Glass shew Rings of Colours also, but if they are wetted with Water, the Colours become more faint and languid, though they vary not in their Species.

*Fourteenthly*, Light incident on thin Plates of Air, Water, or Glass, is disposed, according to the different Thicknesses thereof, to be either transmitted or reflected; where the Thicknesses are as the Numbers 1, 3, 5, 7, 9, &c. the Rays are disposed to be reflected, and transmitted at the Thicknesses expressed by the Numbers 0, 2, 4, 6, 8, 10, &c. And this Action or Disposition of Rays, in its Propagation, intermitting and returning by equal Intervals (as here specified) for innumerable Vicissitudes, occasioned Sir *Isaac Newton* to say — they were then in *Fits of easy Reflection*, or in *Fits of easy Transmission*.

These Observations afford the following Conclusions concerning the *Colours of natural Bodies*.

1. The Particles of all Bodies consist of very thin Plates, or Laminæ of Matter, in themselves clear and pellucid; this in some Measure is evident, by viewing the Particles of *dry Earth*, or *Sand*, with a Microscope.

2. These very thin Plates do reflect or transmit Light incident upon them, and thereby become coloured.

3. The Colours of Plates depend on their Thickness and Density, and not on the encompassing Medium.

4. The



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trary, it is a Mixture of all those seven original *Colours* together; or a Composition of *Colours*, even all the *Colours* in Nature: And, on the other Hand, *Black* is properly no *Colour* at all, being only the Hue of those Bodies whose Substance absorbeth all the *Rays of Light*, and therefore, by reflecting none, cannot, of Consequence, be coloured at all.

A. Then those Bodies which appear *White*, I apprehend, are so by reflecting promiscuously all the *Rays of Light* which fall on them \*?

B. Yes, they are so. I have one Thing more very curious on this Head of *Colours* to relate to you, and then, if you please, we will make a Transition to another Subject.

4. The thinner the Plate, the more vivid the Colours.

5. The more the Thickness of a Plate is increased, the more Colours it reflects, and different ones.

6. The Colour of some Plates will vary, by changing the Position of the Eye, while others remain always the same.

7. The thickest Plates reflect the *red Rays*, and the thinnest the Violet-coloured ones.

8. The denser the Medium encompassing the Plates, or which fills the Pores of Bodies, the more obscure and darker are the Colours.

9. All Bodies appear of such a Colour, as arises from the Mixture of reflected Rays.

10. The more simple and vivid the Colours, the lesser and more dense are the constituent Particles or Plates of natural Bodies.

For a larger Account of these Things, see Sir *Isaac Newton's* Optics, Book II. *Gravesande's* Elements, Vol. II. Book 3. Chap. 22, 23. *Worster's* Prin. of Nat. Philosophy, Page 239 to 252. *Harris's* Lex. under the Word *Colour*.

\* Thus Sir *Isaac* proved by several Experiments (besides bare Reasoning) in mixing coloured Lights, and coloured Powders, in proper Proportions; for the Composition was of as perfect a Whiteness as any in Nature: As may be seen at large in his Optics, Book I. Part II. Prop. 5.

A. Pray,

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*A.* Pray, what is that? I long to know, being ravished with these natural Curiosities.

*B.* It is this: Sir *Isaac Newton*, by Experiments, hath found that the *Colours of Light*, with Respect to their Quantity, were in Proportion to the *seven musical Notes*, or *Intervals of Sound*, contained in an *Octave*, viz. *Sol, la, fa, Sol, la, mi, fa, Sol.* Fig. XIII. of Plate VIII, fronting p. 120.

*A.* A Discovery indeed! sure the happiest Man that ever lived for Experiment. What! musical Harmony in *Colours*!

*B.* Yes, he discovered it thus: He caused a Sun Beam to be largely refracted on the Side of a dark Chamber, which produced the *Spectrum of Colours*, represented by ABCDEF; in which he caused an Assistant exactly to mark the Confines of each *Colour*, by drawing parallel Lines betwixt each, as *am, bi, ck, &c.* and thus the Spaces V, I, B, G, Y, O, R represent the Quantity of the respective *Colours*, viz. *Violet, Indigo, Blue, Green, Yellow, Orange, and Red*: And upon a nice Examination, he found the parallel Sides of the *Spectrum* AF and CD to be divided in the Points *a, b, c, d, &c.* just in the Proportion as a musical Cord is divided for the Concords of an *Octave*, viz. as the Intervals of these Numbers,

$1. \frac{8}{9}. \frac{5}{8}. \frac{3}{4}. \frac{2}{3}. \frac{3}{5}. \frac{2}{5}. \frac{1}{2} *$

I

*A.* This

\* See Sir *Isaac's Optics*, Book I. Part II. Prop. 3. where you have not only the Original of this excellent Discovery, but also a Method deduced from thence to determine of the Sines of Refraction proper to each of those Colours. For when the Sine of Incidence was 50, he found the Sine of Refraction for the least

## Of the musical Harmony of Colours. 79

A. This would induce one to think there were some Kind of Relation between *Musick* and *Colours*; since it hence appears, that in Nature, the pleasing Notes of the one, and the Quantities of the other, are in the same Proportion, and both designed to delight and please Mankind, and sooth the Cares of Life.

B. One Thing more I must remind you of, and that is this: Some Persons tell us, *Colours* are tangible Qualities, and may be distinguished by *Feeling*, and give an Instance of one that could and did do it: But this is certainly impossible to do naturally; and therefore if any one ever did do it, he must have a miraculous *Gift of Feeling* \*.

least refrangible, or reddest Rays, was 77; and for those which were most so, or deepest Violet, was 78; and for the intermediate Colours he found

|                 |   |        |   |                    |   |                 |    |                 |   |
|-----------------|---|--------|---|--------------------|---|-----------------|----|-----------------|---|
| The<br>Sines of | { | Red    | } | Rays extended from | { | 77              | to | $77\frac{1}{8}$ | } |
|                 |   | Orange |   |                    |   | $77\frac{1}{8}$ | to | $77\frac{1}{3}$ |   |
|                 |   | Yellow |   |                    |   | $77\frac{1}{3}$ | to | $77\frac{1}{2}$ |   |
|                 |   | Green  |   |                    |   | $77\frac{1}{2}$ | to | $77\frac{2}{3}$ |   |
|                 |   | Blue   |   |                    |   | $77\frac{2}{3}$ | to | $77\frac{3}{4}$ |   |
|                 |   | Indigo |   |                    |   | $77\frac{3}{4}$ | to | $77\frac{7}{8}$ |   |
|                 |   | Violet |   |                    |   | $77\frac{7}{8}$ | to | 78.             |   |

\* Mr. Derham, in his *Physico-Theology*, (Page 144) asserts, that Colours may be distinguished by the *Touch*, or *Sense of Feeling*; and to confirm this, relates a Story (from *Grimald. de Lum. & Col. Pr. 43, § 59.*) of one at the Court of the Duke of *Tuscany*, who, on a Piece of Silk uniformly woven, and tinged with many Colours, being offered to him, did truly, by that Sense only, judge of the Colours of every Part. — But since Colours are but *Qualities*, and no *material* Essences, I cannot be induced to believe this extraordinary Person could discern Colours merely as such by Feeling, but rather from some small Differences in the Surface of Silks and other Bodies tinged with various Colours, and occasioned thereby; which is a Thing that not only he, but many, who deal in dyed Commodities, have been able to do also.

C H A P.



## C H A P. VIII.

*Of Sound.*

**B.** **L**ET us next entertain ourselves with a Consideration of the Nature and Property of *Sound*; for this is no barren Part of Nature, nor a useless Speculation, the Curious know.

**A.** Come on then, *Sir*: If you are not tired, I never shall with these noble Disquisitions and Enquiries; and pray tell me, first, wherein *Sound* doth consist?

**B.** *Sound* is the undulatory or wave-like Motion of the Air, arising from the *tremulous* Motion of the Parts of any Body, occasioned by a Stroke; and those Undulations or Pulses of the Air beating on the *Tympanum*, or Drum of our Ears, convey, by the Nerves, this Sensation to our Minds \*.

How doth it happen that one and the same *Sound* may be heard by so many at once, and in different Places?

\* Let AB be a String strained and fixed at the Ends A and B; and then let it be drawn out of its natural Position AB into another ACB; if then it be let go, it will by its Elasticity not only fly back again to its first Position AB, but into another ADB, which is so far above AB, as ACB was below it; after this, it will return again almost to C, and then return almost to D; and these *Courses* and *Recourses* of the String growing lesser and lesser above and below AB, it will at last settle into its first and natural Position, and be again at rest. And this is what is called the *Vibration* of a Chord or String drawn tight, and struck, as in musical Instruments. See Fig. XXVI. of Plate V, fronting p. 75.

B. Because the Vibrations and Tremors of the Air, excited by the Percussion of any Body, are propagated in concentric Spheres all around the said Body (which is their common Center) to very great Distances ; and therefore let a Person be any how, or any where situated within the Verge of those Motions, he will equally hear the *Sound*, at equal Distances from the Body whence it comes : See *Fig. XIV. of Plate VIII*, fronting *p. 120*, where DD represents a Drum, and D, 1, 2, 3, 4, 5, &c. the circular Pulses of the Air, made by and conveying the *Sound* of the Beats to our Ears \*.

A. How is it to be proved, that Air is thus the Medium of *Sound* ?

B. By the Experiment of a Bell in the Receiver in an *Air-Pump*, which, before the Air

\* As there is a manifest Agreement between *Light* and *Sound* in many Particulars, so it is most of all considerable in *Reflection* from hard Bodies. For as *Light* is rendered more intensely bright and hot, by being reflected from the concave Surfaces of Mirrours to a certain Point (*viz.* the *Focus*) where the Rays are crowded into a lesser Space ; so *Sound* being uttered within a long and narrow Space, as that of the *Stentorophonic Tube*, or *Speaking Trumpet*, is continually reflected, and reverberated from the curved Sides into the Axis, whereby it becomes more intense and strong at its Exit, is consequently much louder, and may be heard much farther, than it could be otherwise.

Thus also, if a small Sound or Whisper be uttered at one Side of a large *Dome*, or concave Hemisphere, (as at the *Whispering Gallery* in *St. Paul's*) suppose at the Point A, (*Fig. XXV. of Plate V*, fronting *p. 75.*) then shall all the Sound striking against the whole hemispheric Concave be reflected to the Points B, B, B, &c. and from thence to C, C, C, &c. and, after several such Reflections, will all be united in the opposite P ; where the Sound will be much more strong, loud, and audible, than at any other Point in the whole Dome or Concave. See *Clare's Motion of Fluids*, Page 341.

F

is

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is exhausted, may be heard to a considerable Distance; but when exhausted, can scarcely be heard at the nearest Distance\*.

*A.* What Velocity of Motion hath *Sound*?

*B.* Very great, but not near so great as that of Light: Mr. *Derham* has found by Experiment, that the mean *Velocity* of Sounds is at the Rate of 1142 Feet in one Second of Time, or a Mile in  $4\frac{1}{2}$  Seconds; and therefore would take up  $17\frac{1}{2}$  Years in passing from the Earth to the Sun, which is near double the Velocity of a Bullet, at its first Discharge from the Cannon†.

\* This Experiment shews also, that Sounds are augmented or diminished proportionally as the Air is condensed or rarefied. Thus it is known Sounds are weaker on the Tops of high Mountains, where the Air is more *rare*, than in low Vallies, where it is more *condensed* by the Weight of the superincumbent Atmosphere. See *Varen. Geog. Gen. lib. 1. cap. 19. Prop. ult.*

|              |   |                                  |          |                           |
|--------------|---|----------------------------------|----------|---------------------------|
| According to | { | Sir <i>Isaac Newton</i>          | { 968 }  | Feet in a Second of Time. |
|              |   | The Hon. Mr. <i>Fr. Roberts</i>  | { 1300 } |                           |
|              |   | Mr. <i>Boyle</i>                 | { 1200 } |                           |
|              |   | Dr. <i>Walker</i>                | { 1338 } |                           |
|              |   | <i>Mersennus</i>                 | { 1474 } |                           |
|              |   | The <i>Florentine Academy</i>    | { 1148 } |                           |
|              |   | The <i>French Royal Academy</i>  | { 1172 } |                           |
| †            | { | <i>Flamsteed, Halley, Derham</i> | { 1142 } |                           |

But the Reader may depend on the last, *viz.* 1142, as very just for a mean Rate of Velocity.

Several good Uses may be made of the Knowledge of the Velocity of Sound. Thus by it we can easily measure the Distance of the Clouds producing *Thunder* and *Lightning*; for suppose from the Moment we observe the Flash to the Moment we hear the Stroke of Thunder, we number four Seconds, then it is plain the Sound has come four Times 1142, *i. e.* 4568 Feet, or somewhat above  $\frac{3}{4}$  of a Mile; and so far distant is the Cloud. In like manner the Distance of Ships on the Sea, &c. is known by *Firing of Guns*.

*A. Can*



*Of the Nature and Motion of Sound.* 83

A. Can you certainly tell how far *Sounds* may be heard?

B. Indeed this is a Matter not altogether certain; but there are Reports of *Sounds* (as the Explosions of great Guns, &c.) which have been heard to the Distance of 180 or 200 Miles\*.

A. Doth not the Wind greatly obstruct the Motion of *Sound*?

B. No, not so much as one would imagine; tho' there is some small Difference in the *Velocity of Sound*, with or against the Wind; but *Sound* is greatly augmented or diminished by the Strength or Weakness of the Wind.

A. Is there any Difference in the Motion of great or small *Sounds*?

B. Mr. *Derham* says, none at all; whether they be loud or languid, of Bells, Guns, &c. great or small, or any other sonorous Body.

A. How do you estimate the Greatness or Intensity of *Sound*?

\* Mr. *Clare* says, a Gentleman of great Veracity, who had lived some Years at *Gibraltar*, affirmed to him, that he has at *Old Gibraltar* heard the Watch-Word of the Night (viz. *All's well*) given by the Centinel to the Patrol on the Ramparts of *New Gibraltar*, in a still serene Night, and the Water perfectly smooth, and that as plain and distinctly, he thought, as he should have done had he been on the Rampart himself. The Bay between the two Places he judged to be about three *Spanish Leagues* over, or above 10 Miles and a half. Motion of Fluids, Page 343, 344. *Derham's Physico-Theol.* Book 4. Chap. 3. Note 27, where he tells us from Dr. *Hearn*, that Guns fired at *Stockholm* in 1685 were heard 180 *English* Miles; and in the *Dutch War*, 1672, the Guns were heard above 200 Miles. See also his curious Experiments on Sound, in the *Phil. Transactions*, No 300; and *Harris's Lex.* under the Word *Sound*.

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*B.* That, *Sir*, is always as the Space passed through by the Particles of undulating Air, in their passive Motion backward and forward \*.

*A.* What further have you to observe concerning the Motion of *Sounds* ?

*B.* They fly equal Spaces in equal Times, and nothing but the Wind can accelerate or retard them ; not the Differences of *Day* or *Night*, *Summer* or *Winter*, *Heat* or *Cold*, *Weather* cloudy or clear, the *Air* heavy or light, &c.

*A.* Pray, *Sir*, tell me the Reason why, after the *Stroke*, the *Sound* of some Bodies, as Bells, the Strings of musical Instruments, &c. continues so long, but weaker and weaker ?

*B.* The *Sound* of Bodies endures in Proportion to the Number of Vibrations made therein by the *Stroke*, each Vibration producing a Wave in the Air, and each Wave repeating the *Sound* ; but still more and more faint, as the Vibrations are less and less, till they entirely cease : This is easy to be observed by the Ear in Bells, and by the Eye in a String under Tension.

*A.* There is one Thing more I had almost forgot to enquire the Reason of, tho' I guess

\* In a warm and rarefied Air, whose *Elasticity* is therefore small, the Strength or Intensity of Sounds is not near so considerable as in a cold and denser Air, when the Elasticity thereof is much greater.

The Velocity of Sound is 52 Times greater than that of a brisk Wind, or Current of Air ; and (as Mr. *Hales* asserteth) it is to that of undulating Water as 865 to 1.

how

how it must be; but I beg your Thoughts of it, *Sir*; it is an *Echo*?

B. This, *Sir*, is no more than the Repetition of *Sound*, made by a Reflection or Repercussion of a Wave of *Sound*, from the Surface of very hard and smooth Obstacles, as Walls, &c. whence flying back, it re-salutes our Ears with the same *Sound* \*.

A. This

\* 1. The Angles of Incidence and Reflection are equal, as well in the Case of Sound as Light; and therefore it is easy to understand where the *Echo* will be heard most distinctly, when the Figure of the reflecting Surface and Situation of the Speaker is known.

2. Thus let AB be the plane Side of a Tower (*Fig. XXVIII. of Plate V, fronting p. 75.*) GH the Declivity of a Hill before it; let a Person utter a Voice at D, and supposing EC perpendicular to the Plane AB, and the Angle DCE equal to the Angle ECF, the Echo of that Voice will be heard at F.

3. The Distance of the Object returning, the *Echo* of one Syllable must be 24 Paces, or an 120 Feet; and for the *Echo* of two Syllables 48 Paces, or 240 Feet, and so on in a direct Proportion; so that an Object returning the *Echo* of 10 Syllables must be distant 240 Paces, or 1200 Feet.

4. The famous *Echo* in *Woodstock Park*, near *Oxford*, returned 17 Syllables in the Day, when the Wind was a little stirring, and 20 in the Night; for then the Air being denser, the Vibrations became slower, and so a Repetition of more Syllables were audible; as Dr. Plot relates in his *Nat. History of Oxfordshire*.

5. Dr. Harris says there is a much finer *Echo* from the North Side of *Shipley Church* in *Suffex*, which in the Night would repeat distinctly these 21 Syllables:

*Os Homini sublime dedit Cælumque tueri  
Jussit, & Erectos* ———

See his *Lex. Tech.* under the Word *Echo*.

Note, (1.) That the Object AB, which reflects the Sound, is called the *Phonocamptic* Object; and the Point C, on which the Sound impinges, is called the *Phonocamptic* Center; from the Greek Word *Φωνή*, a Voice or Sound, and *κάμπτω*, to bend or inflect.



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*A.* This is just as I apprehended it to be; But pray, *Sir*, whence ariseth the great Variety in the Note or Tone of *Sounds*?

*B.* The Notes and Tones of *Sound* arise from the peculiar Nature of the sonorous Body, the Manner and Degree of Percussion, and the different Make and Configuration of the Organ or Instrument of *Sound*; all these contribute to make that wonderful Variety and Difference in the Tunes, Notes, or Tones of *Sound*\*.

*A.* Why

*Note, (2.)* That as the Science of Vision is called *Optics*, so the Science of Sound or Hearing is called either *Acoustics*, from ἀκουω, to hear; or *Phonics*, from φωνη, a Voice or Sound. All *Catacoustics* is that Part which treats of *reflected* Sounds, Echo's, &c. and *Diaoustics*, the other Part which explains the Nature of *refracted* Sounds; and lastly, those Instruments which are used to assist or improve the *Sense of Hearing*, are called *Otoustics*, from ὤς, ὠτὸς, an Ear, and ἀκουω, to hear.

\* I shall here observe a few Things concerning *Sound* considered as the Subject of the excellent Science of *Music*.

1. Sounds, as they are more *intense* or *remiss*, are said to be *loud* and *low*, or *strong* and *weak*; which depends on the Nature of the sonorous Body, its *Figure*, the *Force* of *Percussion*, &c.

2. The same *loud* or *low* *Sound* hath divers Degrees of *Note* or *Tone*, which are in the Extremes called *Acuteness* and *Gravity* of the *Sound*; in the lower Degrees, the *Note* or *Tone* is *grave*, *flat* or *low*; in the higher, it is *acute*, *sharp* or *high*.

3. The Degrees of *Acuteness* and *Gravity* make all the different and distinguishable *Tones* or *Tunes* of a *Voice* or *Sound*; which are the component Parts of *Harmony*.

4. *Sound* is again distinguished into *long* and *short*, which relates to the *Duration*, or *Continuance* thereof.

5. Farther, Sounds are *Simple* or *Compound*: A *Simple* *Sound* is the Product of *one Voice*, or individual Body, as that of one *Wire* or *Word*. A *Compound* *Sound* consists of several simple ones, all united in the same Measure of *Time*, or striking the *Ear* altogether. As the various Notes struck at the same *Time* on different Instruments in a *Concert*.

A. Why is it that some Notes, called Con-  
cords, are agreeable to the Ear, and others we  
call Discords, disagree thereto?

B. We

6. Lastly, Sounds are either *smooth* and *even*, or *rough* and *harsh*; also *clear* and *distinct*, or *hoarse* and *obtusé*. To produce a smooth, even, and clear Sound, the Body must be homogeneous in its Parts, and of an uniform Figure throughout; otherwise, rough, obtuse, and grating Sounds will ensue. The former of these are only concerned in *Music*, and are therefore called *harmonic*, or *musical* Sounds.

7. As Sounds are produced by the *Vibrations* of the Parts of Bodies, and *Strings* or *Chords* are the most simple and proper Subjects to examine these Matters in; so it has been found that the following Articles, respecting *Chords* and their *Vibrations*, are founded in Nature, and confirmed by repeated Experience.

8. The Forces requisite to draw any Chord or String ACB out of its Place (*Fig. XXIX. of Plate V, fronting p. 75.*) to the Distance of *ce*, *cf*, *cg*, are directly proportional to the Spaces, or Lines, *ce*, *cf*, *cg*.

9. The Vibrations, therefore, of the same Chord are all performed in equal Spaces of Time; that is, the Chord will return from the Situation AgB as soon as from AeB to ACB, because the Force at *g* is as much greater than the Force at *e*, by which it returns, as Cg is greater than Ce.

10. If Chords differ only in *Tension*, the Times of their Vibrations are inversely as the Square Roots of the Weights which stretch them; that is, if the Weights are as 4 to 9, the Times will be as 3 to 2.

11. The Number of Vibrations in the *same Time*, are directly as the Square Roots of the Weights; that is, as 2 to 3, in the preceding Case.

12. The Number of Vibrations made in the same Time by two Chords differing in Thickness, are as the Diameters of their Bases inversely.

13. If Chords differ only in *Length*, the Times of their Vibrations are directly proportional to their Lengths; and the Number of Vibrations in the same Time are inversely as the Lengths.

14. Hence Chords of different Tensions, Diameters, and Lengths, may be so adjusted, by compounding the foregoing Ratios, that the Times of their Vibrations shall be in any given Proportion; which is of great Use in stringing Instruments, as the *Spinnet*, *Harpsichord*, &c.

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B. We may say, they are so from the Agreement or Disagreement of the different Motions

15. As the *Tune* of a Note or Sound is constituted by the Measure and Proportion of Vibrations, in respect of their Velocity, the quicker Vibrations making the *acuter* Tone, and the slower the *graver* one; so it follows, the *Tune* of any String's Note will be *acuter* or *graver*, in Proportion as it is *smaller* or *greater*, *shorter* or *longer*, *tighter* or *slacker*.

16. Two or more Notes or Sounds being made together, are called a *Consonance*; if the Sounds are of the same *Tune*, they are called *Unisonance*; if of different Degrees of *Tune*, *i. e.* of *Acuteness* or *Gravity*, but yet make an Effect agreeable to the Ear, they are called *Concordance*; otherwise *Dissonance*.

17. A *Concord*, therefore, is the Agreement between two Sounds or Notes of different *Tunes*, either in *Consonance* or *Succession* of Sound; such as is pleasing and delightful to the Ear.

18. As the Vibrations of Chords are the Cause of Sounds in general, so the *Coincidences* of the Vibrations of Chords are the Reason and Ground of *Concordance*: If there be two Chords, A, B, whose Lengths are as 4 to 3, then it is plain (by the 13th hereof) that while the Chord A makes three Vibrations, the Chord B will make 4; and therefore supposing them to begin together, there will be constantly at every three Vibrations in A, and four in B, a *Coincidence* of Vibration; that is, they will then vibrate together, and begin each Period of Vibration so long as they continue in Motion. This makes them concord with each other, and produce an agreeable Sound.

19. The more frequent these *Coincidences* are, the more agreeable is the *Consonance*; and therefore Unison is the first Degree of *Concord*, because there the Vibrations begin and end together; this is expressed by the *Ratio* of one to one, *viz.* 1 : 1. Next to this the *Ratio* of 1 : 2 is the most agreeable and perfect *Concord*, and then 2 : 3; after which, the *Concordance* becomes less perfect and pleasant in the *Ratios* 3 : 4, 4 : 5, 5 : 6, beyond which the *Consonance* is insufferable; for in these the *Coincidences* of Vibrations become less frequent.

20. Besides these *Ratios* of *Concord* found in the natural Order of Numbers, 1 : 2 : 3 : 4 : 5 : 6, there are some others, *viz.* 3 : 5, and 5 : 8, which the Ear adjudgeth *Concords*, tho' in a lower Degree. And hence, it is plain, there is somewhat besides the Frequency of the *Coincidences* of Vibrations, that qualifies the *Ratio* for *Concordance* or pleasing Sound; for else



Motions in the Air producing them; but a Person

4 : 7, or 5 : 7, both Discords, would be preferable to 5 : 8, a Concord contrary to Experience.

21. If one certain String be struck, in order to compare the Sounds of others with its own, it is called the *Fundamental*; and its Note is called the *Key* or *Key Note*. A Table of all the Concorde between the *Ratio* of *Unison* 1 : 1, and the *Octave* 2 : 1, expressing the Lengths, Vibrations, Coincidences, Names, and Perfections thereof, you have here subjoined.

| Length. | Vibrat. | Coin. |     |      | Names.         | Perfection.   |
|---------|---------|-------|-----|------|----------------|---------------|
| 1 : 1   | 1 : 1   | 1     | 100 | 1000 | Unison.        | Most Perfect. |
| 6 : 5   | 5 : 6   | 5     | 120 | 833  | Third Lesser.  | Imperfect.    |
| 5 : 4   | 4 : 5   | 4     | 125 | 800  | Third Greater. | Imperfect.    |
| 4 : 3   | 3 : 4   | 3     | 133 | 750  | Fourth.        | Imperfect.    |
| 3 : 2   | 2 : 3   | 2     | 150 | 666  | Fifth.         | Perfect.      |
| 8 : 5   | 5 : 8   | 5     | 160 | 625  | Sixth Lesser.  | Imperfect.    |
| 5 : 3   | 3 : 5   | 3     | 167 | 600  | Sixth Greater. | Imperfect.    |
| 2 : 1   | 1 : 2   | 1     | 200 | 500  | Octave.        | Perfect.      |

22. This Table wants but little Explanation; take an Example of the 5th; the Length of the Chords sounding this Concord must be as 3 to 2, their Vibrations then performed in the same Time, will be as 2 to 3; the Coincidence of these Vibrations will be at every 2d Vibration of the Fundamental; the Chord, which is a 5th, makes 150 Vibrations, while the Fundamental makes 100. The same Chord is 666 of such equal Parts as the Fundamental contains 1000. It is called a *Fifth*, as being the 5th Note from the *Key* inclusive; and is a perfect Concord.

23. To divide a Right Line so as to exhibit the seven Concorde, is very easy; for let AB be the given Line, (*Fig. XXX.* on *Plate V*, fronting *p. 75.*) divide it into two equal Parts in C; and divide CB into two equal Parts in D; and lastly, divide CB into two equal Parts in E.

$$\text{Then is } \left\{ \begin{array}{l} \text{AC to AB} \\ \text{AC to AD} \\ \text{AD to AB} \\ \text{AC to AE} \\ \text{AE to AD} \\ \text{EB to AE} \\ \text{AE to AB} \end{array} \right\} \text{ as } \left\{ \begin{array}{l} 1 : 2, \text{ An Octave.} \\ 2 : 3, \text{ A Fifth.} \\ 3 : 4, \text{ A Fourth.} \\ 4 : 5, \text{ A Third Greater.} \\ 5 : 6, \text{ A Third Lesser.} \\ 3 : 5, \text{ A Sixth Greater.} \\ 5 : 8, \text{ A Sixth Lesser.} \end{array} \right.$$

Person is little the wiser for that: I therefore  
resolve

24. Of these seven Concords, three of them are *simple*, the rest *compound*. The simple Concords are 5 : 6, a third less, 4 : 5, a third greater, and 3 : 4, a fourth; for these cannot be parted into any other Concords, by putting any *mean Number* (whether *Arithmetical* or *Harmonical*) between the Terms of the Ratios.

25. But the other four Concords are composed of the simple ones, as is plain by interposing an *Arithmetical* or *Harmonical Mean*, or both, between the Terms of the Ratios of these Concords, as in the following Table.

*With Arithmetical Means.*

A Fifth, or 2 : 3, contains 4 : 5 : 6, a 3d greater and 3d less.  
A Sixth, G. or 3 : 5, contains 3 : 4 : 5, a 4th and 3d greater.  
An Octave, or 1 : 2, contains 2 : 3 : 4, a 5th and 4th.

*With Harmonical Means.*

A Fifth, 2 : 3, contains 10 : 12 : 15, a 3d lesser and 3d greater.  
A Sixth, G. 3 : 5, contains 12 : 15 : 20, a 3d greater and 4th.  
An Octave, 1 : 2, contains 3 : 4 : 6, a 4th and 5th.  
Also between the Terms of a Sixth lesser, 5 : 8, you put the Mean 6, it resolves it into 5 : 6 : 8, a 3d lesser and 4th.

26. If between the Extremes of the Octave 6 : 12, we put an Arithmetical Mean 9, it resolves it into 6 : 9 : 12, a 5th and 4th. If you put an Harmonical Mean 8, it resolves it into 6 : 8 : 12, a 4th and 5th. If both the Means are interposed, the Series will be Geometrical, *viz.* 6 : 8 : 9 : 12. Thus it appears, that a 4th and 5th are the two Concords that the Octave is immediately resolvable into.

27. The Relations of a 3d, 4th, 5th, 6th, an Octave, to the *Fundamental*, are called *Primary Relations*, and are Concords therewith, as we have seen: But the Relations of Concords to each other, are called *Musical Relations*, and these ought to be all *concord*, to make or stand together in Harmony. Thus the 3d greater, 5th and Octave, make perfect Harmony; for the 5th is to the 3d greater, as 5 : 6, a 3d lesser; the Octave to the 3d greater, as 5 : 8, a Sixth lesser; the Octave to the 5th, as 3 : 4, a Fourth. But the 4th, 5th, and Octave, cannot make Harmony, because the Ratio of the 5th to the 4th is as 8 : 9, which is a Discord.

28. Har-

resolve it into the Will, Power, and Goodness  
of

28. *Harmony* is a compound Sound, consisting of three or more simple Concords in Consonance, and therefore all *Discords*, in the *primary Relations* especially, and also in the *mutual Relations* of the acute Terms of the Ratios, are absolutely forbidden. Though it is true, *Discords* are used in *Music*, yet their Use is only to make the *Concords* appear more agreeable by the Opposition.

29. The *Intervals* of Concords are termed *harmonious*; the *Intervals* of *Discords* are of two Sorts; the first are called *Concinnous Intervals*, because they are fit for Music in Combination with those of the *Concords*, being in themselves neither agreeable nor very disagreeable. They arise from the Differences of the Concords. Thus the Difference between a 4th and a 5th, *viz.*  $\frac{3}{4}$  and  $\frac{2}{3}$ , is  $\frac{1}{12}$ , or 8 : 9; this constitutes the Note which is called the *Second greater* from the *Fundamental*, and the Difference between a 3d greater and 4th, is 15 : 16, and this makes the *Second lesser*, which is the very next the *Fundamental*.

30. The Ratio 8 : 9 is called a *greater Tone* or Interval, 9 : 10 a *lesser Tone*, and 15 : 16 a *Semitone*, or rather, an Interval greater than half, and less than a whole Tone. Now if from a *lesser Tone* 9 : 10 (the Difference of a 3d lesser and 4th) you take an Octave 1 : 2, there will remain the Ratio 5 : 9, which is the Note above the 6th greater, *viz.* the *Seventh lesser*; and the *Seventh greater* is the Difference between the *Semitone* 15 : 16 and the Octave 1 : 2, *viz.* the Ratio 8 : 15. And thus you have all the Intervals both *Harmonious* and *Concinnous* which constitute the Notes in present Use; the rest are all *inconcinnous*, which produce very harsh Notes, or gross *Discords*, too bad to be used in Music.

31. The First or *Fundamental* Note of any Tune or Song, is called the *Key*, as being that to which all the Notes in the Melody of that Song are referred, and by which they are governed and regulated. In this Key the Melody generally begins, and always closes. The Key is distinguished into two Kinds, *viz.* the *Flat* and *Sharp Key*.

32. The *Flat Key* is that which hath always the 2d greater, 3d lesser, 4th, 5th, 6th lesser, 7th lesser, and Octave; the *Sharp Key* has the 2d greater, 3d greater, 4th, 5th, 6th greater, 7th greater, and Octave. Whence it is plain, that the *Air* or *Tone* of the Melody in the Flat Key is a *half Note* lower than it is in the Sharp Key; and is therefore more suited to, and generally used in the *melancholy* and *mournful*, than *brisk* and *airy* Tunes, which the other Key is adapted to, being half a Note higher.

33. These



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of the great Creator, who, doubtless, designed the pleasing Harmony and Melody of *Sounds* to

33. These *seven natural Notes* are generally represented by the seven Letters, A, B, C, D, E, F, G, in a single Octave. If the Key be *Sharp*, the 3d, 6th, and 7th above have this Mark (\*) affixed to the Characters of these Notes to denote it; as thus, if A be the Key, A, B, C\*, D, E, F\*, G\*; or if the Key be *Flat*, they have this Mark (<sup>b</sup>), as A, B, C, D, E, F, G<sup>b</sup>.

34. This Division of the Octave is most natural, and because it contains three *greater Tones*, two *lesser Tones*, and two *Semitones*, is called the *DIATONIC SCALE* of Music, but more vulgarly the *GAMUT*, from the Name of the lowest Note therein.

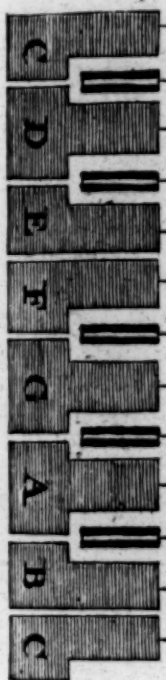
35. The *Gamut* contains three Parts, called *Clifts*, the *Base*, the *Tenor*, and the *Treble Clifts*, as represented in *Fig. XXXI.* of *Plate V*, fronting *p. 75*; each Part singly contains five Lines, on which, and in the Spaces between them, are wrote the Characters of the Notes. The Marks of the Clifts, and Names of each Part, you there see expressed. Part of the Tenor is common to the Base below, and the Treble above.

36. Musicians, in writing Music, use various Characters to express Notes of different Length of Time, as *Breve*, *Semibreve*, &c. any one of which contains two of the next below, in *common Time*; but in what is called *Triple Time*, a Semibreve contains  $1\frac{1}{2}$  Minims, 3 Crotchets, 6 Quavers, &c. See *Fig. XXXII.* of *Plate V*, fronting *p. 75*.

37. I have thought it expedient to illustrate the foregoing Rudiments of the Theory of Music, by an Example of an Octave in the Base Clift of a *Spinnet* (*Fig. XXXIII.* of *Plate VI*, fronting *p. 92.*) where you observe a Scale divided into an 100 equal Parts; opposite to which are placed the Strings which sound the 12 Notes or Semitones of the Octave; at the lower End, are the Keys of the seven natural Notes, marked with the Letters C, D, E, F, G, A, B, C, between which are the other Keys of the Semitones. The Key Note is C, with respect to which the Strings of the other Keys are proportioned in Length, as they are 2d, 3d, 4th, &c. to it. On each String are Numbers, shewing how many equal Parts of the Scale it contains; and others which shew the Ratio of its Length to that of the Key or Scale. From the Ends of the Strings go dotted Lines to the Notes of a Tune wrote in the *Gamut*, in their proper Lipes and Spaces. On the left of the Scale of equal Parts is the *Diatonic Scale*, shewing, both in the *Flat* and *Sharp Keys*, the Intervals of the *Tones* and *Semitones*, and their Order in each.

38. Thus

| The<br>Diatonic Scale | Flat Key  |        | 10 | 20 | 30 | 40 | 50 | 60 | 70 | 80 | 90 | 100 |
|-----------------------|-----------|--------|----|----|----|----|----|----|----|----|----|-----|
|                       | Sharp Key | London |    |    |    |    |    |    |    |    |    |     |



| 100  |          |  |
|------|----------|--|
| 937  | 15 to 16 |  |
| 888  | 9 to 10  |  |
| 833  | 5 to 6   |  |
| 80.  | 4 to 5   |  |
| 75.  | 3 to 4   |  |
| 71.4 | 5 to 7   |  |
| 666  | 2 to 3   |  |
| 625  | 5 to 8   |  |
| 60.  | 3 to 5   |  |
| 555  | 5 to 9   |  |
| 533  | 8 to 15  |  |
| 50.  | 2 to 2   |  |

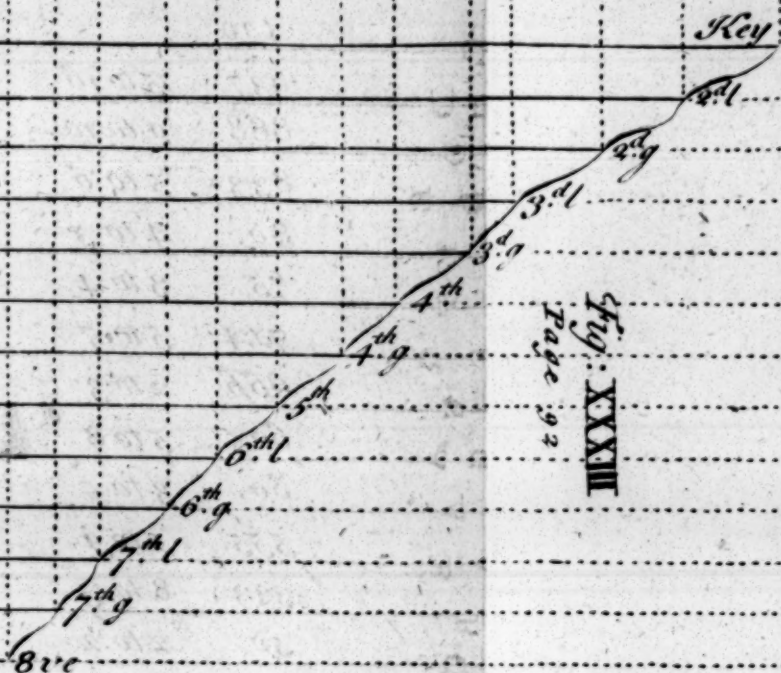


Fig. XXXV.

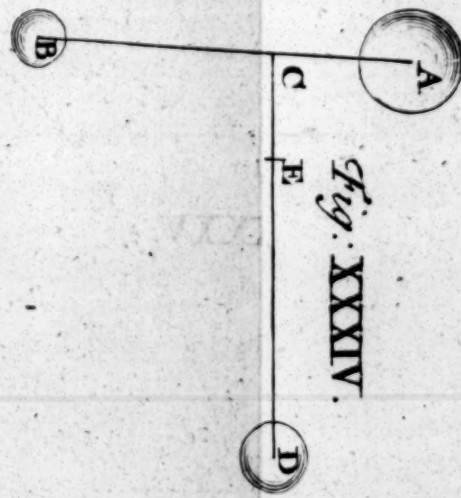
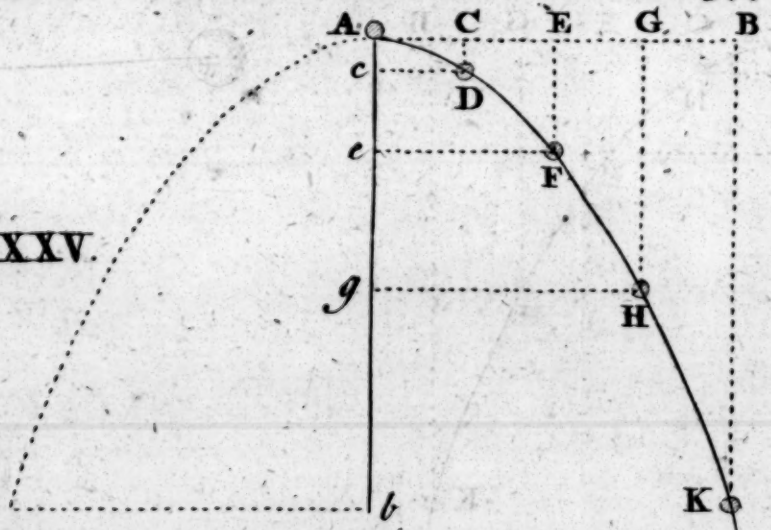


Fig. XXXIV.







to sweeten and heighten the Pleasures of human Life, and to alleviate and dispel its Cares \*.

38. Thus much shall here suffice for a short Sketch of the *Theory of Music* ; they who would see more, may read Dr. *Holder's* Grounds of Harmony ; *Salmon's* Theory of Music. in *Philos. Transf.* N<sup>o</sup> 302 ; *Malcolm's* excellent Treatise of Music, *Jackson's* large Scheme of Music ; and *Harris's* Lex. Tech. under the Word *Music* ; besides various others.

\* Among all the wonderful Effects ascribed to the Power of Music, none is more surprising and important than that of curing the venomous Bite of the *Italian Spider*, called the *Tarantula*. The Part bitten is soon affected with a very acute Pain, and a few Hours after with a Numbness ; upon which ensues a profound Sadness, and a difficult Respiration ; the Pulse grows weak, the Sight is disturbed, and the Person loses Knowledge, Sense, and Motion. The Doctor is consulted in vain ; the Musician here alone performs the Cure ; he tries a Variety of Airs, and when he chances to hit on that Harmony that accords with the Patient, he begins to move by Degrees, and keeps Time with his Fingers, Arms, Legs, and Body ; then he raises himself up and dances, increasing in Strength and Activity. This dancing Fit continues six Hours, or a Day, or sometimes two Days. When the Music ceases, the Person gives over dancing, and is put to Bed. This Process is repeated till the Patient has recovered himself, which is by little and little ; and every sick Person has a particular Air or Tune, and always a very sprightly one. See *Philosophical Conversation*, Vol. II. *Conv.* 15. Also *Derham's* Physico-Theology, Book IV. Chap. III. *Malcolm's* Music, Chap. XIV. § 3. &c.

C H A P. IX.

*Of GRAVITY and LEVITY: Of ATTRACTION and ELECTRICITY.*

*A.* **W**HAT is meant by the *Gravity* of Bodies?

*B.* That Property, Power, or Force, whereby all Bodies tend downwards, in right Lines, to the Center of the Earth.

*A.* Is not this what is called the *Weight* of Bodies?

*B.* No; for the *Weight* is properly the Effect of *Gravity*, or the Measure or Quality of this Power acting on them.

*A.* How do you distinguish the Kinds of this Property?

*B.* Into absolute and specific *Gravity*.

*A.* What is absolute *Gravity*?

*B.* All that Power whereby a Body tends towards the Center of the Earth.

*A.* And how doth specific *Gravity* differ therefrom?

*B.* The specific, or relative *Gravity*, is that which is peculiar and appropriate to any distinct Species of Bodies, and distinguisheth them from others, when compared with them.

*A.* What is the Measure of *Gravity* in Bodies?

*B.* Their

B. Their Quantity of Matter; for their *Weight* or *Gravity* is always proportional thereto.

A. Pray what do you call that Point towards which Bodies naturally tend?

B. The Center of *Gravity*, which is very near the Center of our Earth, for all Bodies within its Verge of Power: And thus the Center of *Gravity* of the Planets is said to be near to the Center of the Sun, about which therefore they all circulate \*.

A. In what Manner doth this Power of *Gravity* act on Bodies?

B. Equally and absolutely on all alike, without Regard to their Figure, Size, or Quantity of Matter.

A. If so, one would think all Bodies would descend with equal Velocity or Swiftneſs.

B. So they would in Reality, were it not for the Reſiſtance of the Air.

\* The common Center of Gravity of two Bodies is a Point ſo ſituated in a right Line joining their Centers, that their Diſtances from it on each Side are reciprocally as the Quantities of Matter in the ſaid Bodies.

*Example.* Let A be a Body of 12 lb, and B another of 4 lb; join their Centers by the Line AB; then ſay, as  $A + B : A :: AB : BC$ , that is, As the Sum of the two Bodies 16 lb is to the greater 12 lb, ſo is the whole Diſtance AB, to the Diſtance BC, which gives the Point C, the common Center of Gravity between them. If a third Body D of 6 lb be added, to find the common Center of all the three Bodies A, B, and C; ſay, as  $A + B + D : D :: CD : CE$ , which gives E, the common Center of all their Gravitation. In this Manner you find the common Center of Gravity for any Number or System of Planets.

For the common Center of Gravity of Lines, Superfices, and Solids, ſee *Wallis's* Mechanics, and other Writers on the mechanical and experimental Philoſophy, particularly *Dr. Deſaguliers's* Courſe, Vol. I. Leſſ. 1ſt and 2d.

A. This



*A.* This is a strange Assertion! Pray how do you prove it?

*B.* By the *Air-Pump*; for put the lightest Feather and a Guinea together in the Receiver, holding them fast at the Top till the Air be exhausted, then letting them go, you will perceive them descend to the Bottom in the same Moment of Time, and with incredible Swift-ness.

*A.* This is indeed very curious and wonderful, and almost past Belief, that the lightest Bodies should descend as soon as the heaviest \*!

*B.* Yes, they will in *Vacuo* indeed; but in the resisting Medium of the Air, Bodies gravitate towards their common Center, and one another, according to their different Quantity of Matter contained in them, as I said before.

*A.* What, *Sir*, do you say that Bodies gravitate towards one another?

*B.* Yes, they do: The *Moon* gravitates to the *Earth*, and so does the *Earth* to the *Moon*;

\* This may seem wonderful at first Thought, but the Wonder will soon cease, if we only consider, that each equal Particle of Matter is acted upon by an equal Force of Gravity, and that therefore every such Particle in one Body must needs descend with the same Velocity that every such Particle does in another. Consequently, if the Matter of the Feather consist of ten Particles, and that of the Guinea *ten Thousand*, it is plain, that since there is 1000 Times more Particles in the latter Case to be moved than in the former, there will be required a thousand Times greater Force of Attraction to move the Guinea, than to move the Feather, with the same Velocity; but this is all the Force that can possibly affect the *Guinea*; the Velocity of Motion therefore in both Cases must be the same; it is the Quantity of Motion only in the *Guinea*, which is a 1000 Times greater than that of the Feather.

the

*Of the Gravitation and Descent of Bodies.* 97

the *Satellites* of *Jupiter* and *Saturn* to them; and *Jupiter* and *Saturn* gravitate to the *Satellites*; yea, the *Earth* gravitates or moves towards the *Stone* that falleth, as well as the *Stone* gravitates or moves towards the *Earth*.

*A.* Aye, indeed, why then, if the *Earth* moves towards all *Bodies* falling on it, how is it that we can never perceive it?

*B.* By Reason of the vast Disproportion of Matter in each; for suppose a *Stone* of 100 solid Feet in Magnitude, let fall from a Height equal to our *Chichester* Spire, viz. 300 Feet; then because the *Globe* contains about 3000000000000000000000000 solid Feet, and suppose the *Earth* every where to be of the same Density with common *Stones*, then the Quantity of Matter in the *Earth* will be to the Quantity of Matter in the aforesaid *Stone* of 100 Feet, as 3000000000000000000000000 to 1; and therefore, while the *Stone* falls 300 Feet, the *Earth* will move towards the *Stone* the  $\frac{300}{3000000000000000000000000}$  or  $\frac{1}{10000000000000000000000000}$  Part of a Foot; which is so very small a Matter, as to be not only imperceptible to the Senses, but inconceivable by the Imagination.

*A.* Very small indeed. But, *Sir*, now we are upon the Descent of heavy *Bodies*, pray at what Rate of Velocity doth a *Body* descend to any given Distance downright?

*B.* The perpendicular Descent of *Bodies*, is at the Rate of 15 Feet in one Second of a Minute; and for all the following Seconds,

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the

98 *The PHILOSOPHICAL GRAMMAR.*

the Spaces are as the Squares of the Seconds : Thus, suppose a Body keeps falling 1, 2, 3, 4, &c. Seconds, the Squares of these Times will be 1, 4, 9, 16, &c. and the Spaces passed through at the End of each will be 15, 60, 144, 240, &c. and the exact Number of Feet passed through in each single Second will be as the odd Numbers, 1, 3, 5, 7, &c. that is, 15, 45, 75, 105, &c. Feet ; all which is distinctly and naturally seen in the Line AB, *Fig. XV. of Plate VIII,* fronting *p. 140 \**.

A. In

\* 1. If then a Body were projected or thrown from the Point A, in the horizontal Distance AB, it would, in an unresisting Medium, and without Gravity, proceed with an uniform Motion ; and, in equal Times, describe equal Spaces AC, CE, EG, GB, &c. But, since all Bodies have Gravity, the same Body A would with its Gravity alone, in the same equal Times aforesaid, descend through the Space Ac, eg, gb, &c. Draw CD, equal and parallel to Ac, and cD the same to AC ; then, because the Body A is urged with two Forces, one in AC, the other in Ac, it will be carried in a Direction between both, and at the End of the first Moment will be found in D, the opposite Angle of the Parallelogram AcDC (according to Note \* in Page 54.) Thus in two such Moments, while it would have described twice the horizontal Space AE, or four Times the perpendicular Space Ac, by single Forces, it would by Composition of those be found in F. And so after three such Moments it will arrive to H ; after four to K, &c. Now since Ac, Ae, Ag, Ab are as the Numbers 1, 4, 9, 16, they are as the Squares of the Lines cD, eF, gH, bK. But this is the common Property of the *Parabola*, as all Writers on Conics demonstrate. Therefore all *Projectiles*, or Bodies thrown in any Direction, describe the Curve of a *Parabola* in their Descent.

2. On this Principle depends the *Art of Gunnery* ; let AN be a Cannon (*Fig. XXXVI. of Plate VII,* fronting *p. 99*) elevated above the horizontal Level AM, in the Angle BAM ; a Bomb discharged from the Muzzle A will leave the rectilinear Direction AB, and describe the parabolic Curve AIM. AM is the Amplitude of the Projection, or horizontal Random of the Bomb ; I, I, is the Height thereof. Now a skilful Engineer knowing the Distance of an Object, as the Spire S, can so  
propor-



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## *Of the Gravitation and Descent of Bodies. 99*

*A.* In what Manner or Proportion does the Weight of Bodies increase or decrease, with respect

proportion the Charge of Powder, and the Elevation of the Mortar, that the projected Bomb M shall describe such a Parabola ALX, as shall pass through the proposed Object S, which therefore must be hit by the Bomb in its Course through that Curve.

3. Since a Body falling freely, descends with a Motion equally accelerated in equal Times, as proved by Experiments, and evident to Reason; and also since the Motion of a Body descending upon an inclined Plane is of the same Kind, as the Mathematicians prove (see *Keill's Introd.* Page 207) the Forces by which two Bodies, A, B, descend, one of which falls freely, the other B runs down an inclined Plane, if they begin to move in the same Moment, are always to one another in the same Ratio, as in the Beginning of the Fall, which Ratio is as the Length of the Plane AE to its Height AD (*Fig. XXXVII. of Plate VII.* fronting p. 99.) See the last Article of Note \*, in Page 54.

4. The Effects of those Forces, therefore, that is, the Spaces passed through by these Bodies in the same Time, are in the same Ratio of the Length of the Plane to its Height. On the Height of the Plane AD describe a Semicircle ACD, this will cut the Plane in C; join CD; then, since the Angle at C is a right one, the Triangles AED and ADC are similar, and so the Ratio of the Side AD to AC is the same as of the Side AE to AD. Consequently, while the Body A descends freely to D, the Body will descend on the inclined Plane to C.

5. In the same Manner it is shewn, with respect to any other inclined Plane AFD, that while a Body A falls freely from the perpendicular Height AD, the Body B let go at the same Time, will arrive on the inclined Plane to the Point G. But AD is the Diameter of a Circle, and AC, AG, two Chords in the same; therefore, a Body falls through the Diameter, or any Chord of a Circle, in the same Time.

6. Let CB be a String with a Weight B at the End, hanging freely from the Point C, (*Fig. XXXVIII. of Plate VII.* fronting p. 99) this is called a *Pendulum*. Let the Weight B be brought to the Point D, and there let go, it will by its own Gravity descend to its first Place B, and then with the Velocity acquired in that Descent will ascend to E, so that BE will be equal to BD; and this Motion or Swing of the Body from D to E is called a *Vibration*.

7. The Bob or Ball of any *Pendulum*, vibrating freely, describes the Arch of a Circle, as DBE, whose Diameter AB is twice the Length of the *Pendulum* CB. If the Arches BD, BE,



respect to their Distance from the Center of Gravity?

B. The

are very small, they do not sensibly differ from the Chords BD, BE; there the Descent of a Body through a *small Arch*, and through its Chord, is performed in the same Time, as far as Sense can discern. But the Descent of Bodies in any Chord is in the same Time, and therefore all Vibrations of the same Pendulum, though unequal, are performed in the same Time.

8. The Velocities acquired in the lowest Point B, by a Body describing different Arches DB, KB, are as the *Subtenses* or Chords of those Arches. See Keill's *Introd. Lect. 15. Theor. 37, and 43.*

9. The Times of the Vibrations of two Pendulums, CB and *cb*, (*Fig. XXXVIII. and XXXIX. of Plate VII, fronting p. 99*) are in the *subduplicate Ratio* (*i. e.* as the Square Roots) of their Lengths, for the Body descends from D to B, in the same Time it would fall freely through the Diameter of the Circle; *i. e.* twice the Length of the Pendulum; therefore it performs one Vibration from D to E in the same Time that it would fall by the Force of Gravity through four Times its Length CB. Thus also the Pendulum *cb* vibrates from *d* to *e* in the same Time it would fall freely through four Times its Length *cb*. But Spaces passed through in this Case, are as the Square of the Times, and therefore the Times are as the Square Roots of the Spaces. Consequently, the Time of a Vibration through DE, is to the Time of a Vibration through *de*, as the Square Root of four Times CB to the Square Root of four Times *cb*, or as the Square Root of CB to the Square Root of *cb*.

10. It has been found that a Pendulum, which shall vibrate Seconds of Time in our Latitude, must be  $39\frac{2}{10}$  Inches in Length; if then it be required to find the Length of a Pendulum, that shall vibrate *half Seconds*; say, as the Square of 1 (which is 1) is to the Square of  $\frac{1}{2}$  (which is  $\frac{1}{4}$ ) so is  $39\frac{2}{10}$  to  $9\frac{8}{10}$  Inches, the Length of the Pendulum required. Thus the Length to vibrate Thirds of Seconds will be found  $41\frac{3}{10}$  Inches; and the Length to vibrate quarter Seconds will be  $24\frac{3}{10}$  Inches.

11. From hence it appears, that a Pendulum is an universal Chronometer, and that by it a Person may measure Time very truly when destitute of a Clock or Watch. For hang up any String with a Bob to it, and let it vibrate; then having numbered the Vibrations performed in the Time proposed, say, as  $39\frac{2}{10}$  is to the Length of the String, so is 1 to a Number, whose Square Root is the Time of one Vibration made by the Pendulum, which multiply by the Number of Vibrations, and you have the whole Time required. So that you divide the Length

B. The *Weight* of Bodies is reciprocally as the Squares of the Distances from the Center of Gravity.

A. I should be glad if you could exemplify this to my Apprehension.

B. That I can easily. Suppose ZPNS the Globe of our Earth, and its Center C, the Center of Gravity; let there be a Body placed on its Surface at Z, whose Weight let be 3600 Pounds; then if this Body be removed to the Distance CF, two Semi-diameters of the Earth, you have its Weight there by this Analogy,

Length of the *Pendulum* by the constant Number  $39\frac{2}{15}$ , and take the Square Root of the Quotient for the Time of a Vibration.

12. Let AB (*Fig. XL. of Plate VII, fronting p. 99*) represent an uniform Bar of Iron, or any other Thing; let this be made to vibrate; and with it hang up a common *Pendulum* CD that shall vibrate in the same Time with it; the Length of such a *Pendulum* CD will ever be found equal to AG, which is  $\frac{2}{3}$  of AB. This Point G is therefore called the *Center of Oscillation*; and has the same Effect, as if all the Weight of the Bar was collected into it: Consequently, if that Point of the Bar be made to strike an Object, the Blow will be greater than from any other Point; for which Reason it is also called the *Center of Percussion*.

13. It is said, that *Ricciolus* was the first who measured Time with a *Pendulum*, and that herein he was followed about the same Time by *Vendelinus*, *Mercennus*, *Kircherus*, &c. some of whom declared they knew nothing of *Ricciolus's* Attempt. But the first who applied it to a Movement, a *Clock*, or *Watch*, was the famous Mr. *Christopher Hugen*, who brought it also to a good Degree of Perfection. See *Lex. Tech. Magnum*, under the Word *Pendulum*; and most mechanical Writers on this Subject. As to what farther concerns the *Doctrine of Projectiles*, I shall leave that to the Chapter of *Hydrostatics*, in the last Part of this Book. And for a compleat *Theory* of the said *Doctrine*, I refer the Reader to *Keill's* Introduction to Natural Philosophy; and for the *Praxis* thereof, or its Application to the *Art of Gunnery*, he may consult the *Young Trigonometer's Guide*, Vol. I, Part II. Chap. V.

4:1::3600:900. If the said Body were removed three Semi-diameters to E, the same Analogy finds its Weight there, viz. 9:1::3600:400. And at the Distance of six Semi-diameters, the Weight thereof will be but 100 Pounds; for 36:1::3600:100. Thus, at the Distance of 1, 2, 3, 4, 5, 6 Semi-diameters from the Center of the Earth, the Diminution of the Weight of such a Body would be as these Numbers, 3600, 900, 400, 225, 145, 100. Thus, on the contrary, he who beareth 100 Pounds Weight on the Earth's Surface, would, with equal Ease, sustain the Weight of 3600 Pounds, at the Distance of  $6\frac{1}{2}$  Diameters, as at A. See *Fig. XVI. on Plate VIII, fronting p. 120.*

A. After so much of the *Gravity* of Bodies, let me know what the Philosophers say of the *Levity* of Bodies?

B. There is no such Thing, philosophically speaking, as absolute *Levity* or *Lightness*; this is only a comparative Term, and implies no more, than the Difference of the Weight of Bodies compared together, or their specific *Gravity*.

A. Pray, what Distinction do you make between *Gravity* and *Attraction*?

B. In the Nature of the Thing there is no Difference, they are both one and the same Principle, only in the Manner of considering it this Distinction ariseth; if we respect it in the Body, containing the Center of *Gravity*, we call this *Power*, in that Body, *Attraction*; but we call it *Gravity* in Bodies which are moved



moved toward that Center, or Body, wherein it is: Thus the Earth is said to attract Bodies on it, or falling on it; and those Bodies are said to gravitate towards the Earth; so the *Loadstone* attracts Steel, and the Steel gravitates to it\*.

## A. Is

\* ATTRACTION is, by the *Modern Philosophers*, considered twofold, viz. (1.) *Attraction of Gravitation*, whereby one Body affects another at a Distance, and causes it to *gravitate* towards itself; which is what I have above considered; and concerning which the Reader may see abundance in *Lex. Tech. Mag.* under this Word. (2.) *Attraction of Cohesion* which we find only among the very small Particles of Matter in Bodies, and of which I shall here enumerate the chief Properties.

1. This Force is then greatest when the Particles are in Contact, or touch each other.

2. In homogeneous Particles, the greater the Surface of Contact, the stronger the Force.

3. The Sphere of this Attraction is inconsiderable at any sensible Distance from the Particle.

4. The smaller the Distance, the stronger the Force, which is very great at very small Distances.

5. This Force decreases nearly as the *Cubes* of the Distances increase; and not as the *Squares* thereof, as in the other Sort of Attraction.

6. This Force is proportional to the Quantity of Matter in Particles.

7. Consequently, the densest Particles, whose Surface of Contact is largest, hath the greatest *Attraction of Cohesion*.

8. In Particles of the same Kind, or equal Density, the Attraction is stronger between small Particles than the large; because in those there is a greater Quantity of Surface than in these, especially if they are of a spherical Form.

From this Property of Matter proceed many wonderful and curious Phænomena, which are easily accountable for on this Principle. As,

1. The strong Cohesion of the Particles which compose solid or hard Bodies; for without this Power, the hardest Adamant would instantly dissolve into an impalpable Powder.

2. The prodigious Cohesion of polished Surfaces, as of Glass, Stones, Metals, &c. Thus two leaden Balls pared with a sharp Knife,

*A.* Is this Power of *Attraction* the same in all Bodies, of the same Kind, of equal Density and Magnitude?

*B.* Yes;

Knife, so as to cut off a Segment about  $\frac{1}{4}$  of an Inch Diameter, if they are pressed together (giving them a little Twist) pretty hard, they will require the Weight sometimes of 100lb. to separate them. That this is not owing to the Air is plain, because they are not separated in the *exhausted Receiver*.

3. By this Power, *Liquids* arise into the Substance of *Bread*, *Sugar*, *Sponge*, and all very porous Bodies.

4. On this Account also *Liquids* rise on the Sides of containing Vessels, and about the Surface of Bodies floating therein, to a small Height above the common Level.

5. Particularly on this Principle, and no other, can we account for the *Ascent* of *Liquids* in capillary Tubes of Glass to so considerable a Height above the Surface of the Liquor in which they are placed, contrary to the Laws of *Hydraulics*; the Heights to which Water will arise in different Tubes, are reciprocally as the Diameters of the Bores of those Tubes, and the Quantities of Water drawn up, are directly as those Diameters. See *Gravesande's* and *Dr. Desaguliers's* Courses. *Webster's* Principles of Nat. Phil. Page 17. *Rowning's* Comp. System. *Harris's Lex. Tech.* under the Word *Attraction*.

6. By this Means, the Water in the Vessel BC (*Fig. XLI. of Plate VII, fronting p. 99*) will arise between the two polished Glass Plates, AC, Ae, being set therein touching each other on the Sides AB, and open a little on the other Sides; the Figure of the Water between the Plates *e, f, g*, is that of an *Hyperbola*.

7. When Particles of Matter of different Densities, Quantities of Surface, and, consequently, of different Attractive Powers, are mixed together, they will necessarily attract, agitate, and move each other in various wise, and with incredible Velocities in many Cases; from hence will arise *Fermentations*, *Ebullitions*, *Excalescencies*, *Fusions*, *Dissolutions*, *Crystallizations*, and other such like Effects known in Chymistry.

8. But among the small Particles of Matter, there is not only an *attractive* Power, but also a *repelling* one, whereby they are made to recede and fly from each other; and this Force is called *Repulsion*.

9. *REPULSION* begins where *Attraction* ends, and increases as the Distance of Particles decrease.

10. Particles attracted most strongly within the Sphere of its Power, are repelled most forcibly when without it.

11. From

B. Yes; but in all such Bodies, the less any one is than another, the greater is its attracting Force; so the *magnetic Attraction* is stronger in a small *Loadstone*, in Proportion to its Weight, than in a larger one.

A. What is the Consequence of this?

B. Sir *Isaac Newton* has found, by Calculation, that, as the Particles of *Light* are the least Bodies we know of, so their *Attraction* is 10000000000000000 Million of Millions of Times greater than that of the Earth, on the Earth's Surface; according to the Quantity of Matter in each, and the aforementioned Velocity of *Light*.

A. Pray, Sir, what do you understand by *Electricity* \*?

B. A

11. From the great Degree of this repulsive Power in *Oil*, *Grease*, &c. arises the great Difficulty of mixing those Bodies with *Water*, so as to make their Parts touch and stick together.

12. This Power is small between *Glass* and *Water*; greater between *Glass* and *Quicksilver*; strong between *Quicksilver* and *Copper*; stronger between *Quicksilver* and *polished Steel*; but weaker between *Quicksilver* and *Gold*.

13. From this Principle it is that a dry *Needle* swims upon the *Water*; and that *Flies*, &c. walk and run thereon without wetting their Feet.

14. Let there be two Balls of Wood, A and B, the one wetted all over with *Water*, the other with *Oil*; let these be put into the Vessel of *Water* CD, and the different Effects of the *attractive* and *repulsive* Powers of Matter and *Oil* will become very visible; the *Water* in one Case rising by *Attraction* above the common Surface; and in the other it is forced below it by *Repulsion*. See Fig. XLII. of Plate VII, fronting p. 99. See more concerning *Attraction* and *Repulsion* of Particles in *Webster's Principles*, *Gravesande's Elements*, and Dr. *Desaguliers's* Courses of Experimental Philosophy; and also the *Lex. Tech.* under the Word *Attraction*.

\* *ELECTRICITY* consists of an *Attraction* and *Repulsion*, pretty much of a like Nature with those in the foregoing Note.



B. A certain Kind of attractive Faculty, peculiar to some Bodies, as *Amber, Jet, Sealing-Wax,*

Note. The principal Properties of these wonderful Qualities of Bodies are as follow.

1. It exists of fine invisible *Effluvia*, supposed to be of an unctuous and oily Nature, which are excited by Attrition, or rubbing the electrical Body till it become warm.

2. Such Bodies warmed by the Fire only, do not attract so forcibly as when heated by rubbing.

3. If a Glass Tube be first warmed by the Fire, and then heated by Attrition, it will attract most speedily and powerfully.

4. *Tersion*, or Wiping, is also necessary, as well as Attrition or Rubbing, to procure *Electricity*; for this frees the Pores for the better Emission of the *Effluvia*.

5. This Effect is much weakened if the Weather be thick and cloudy.

6. The Interposition of the finest Linen or Paper will hinder the Action of *Electricity*; whereas the *magnetic Virtue* pervades all Objects.

7. *Electrical* Bodies attract all Things indifferently, the *Load-stone* only Iron and Steel.

8. If a Glass Tube be rubbed in the Dark, the *Effluvia* will appear lucid; and if a little Brush be held near the Tube, or drawn along it without touching, just after it is rubbed, Sparks of Light like Stars will appear upon every Hair of the Brush.

9. If when a Tube is just rubbed, your Hand be brought along down very near by the Tube, it will prevent its Effect.

10. If the Fingers be moved nimbly by the Tube, as if you went to strike it in a Direction perpendicular to its Axis, the *Effluvia* will be heard to snap against the Finger, or (beat back from it) against the Tube, like the Crackling of a green Leaf in the Fire, but not so loud.

11. In hot and moist Weather, the Tube requires a great deal of rubbing before it will snap, and its Virtue will then diffuse itself but a little Way, for what it will when the Weather is dry and cold.

12. In fine dry Weather, the *Electrical Virtue* will attract at the Distance of eight or ten Feet: In close moist Weather, not above the Distance of two Feet.

13. After a Feather is attracted, and has stuck to the Tube some Time, it will fly off, or be repelled, and never return to the Tube again till it has touched some other Body.

*Wax, Glass, &c.* whose Particles are such, that being greatly rarefied and agitated, (by the Heat occasioned by *Attrition*, or rubbing of them) they fly off to a certain small Distance, but not beyond the Sphere of the Body's *Attraction*; and therefore, by this *Attraction*, they are obliged to return again to their old Quarters.

A. Why then, I suppose, it is by their flying off, that light Bodies, as *Feathers, Hairs, &c.* are repelled from the electrical Body; and by the Return of those Particles, they are again instantly compelled back, and attached to the said Body.

B. Yes, that is the Case, as understood at present; but for the real Cause of *Attraction* or *Gravity* in general, Sir *Isaac Newton* professeth himself entirely ignorant of it; even though he makes this Principle of *Attraction* or *Gravity* the Basis of all his Philosophy: Where-

14. If the Finger, &c. be held near the Tube, the Feather will alternately fly from the Finger to the Tube; always stretching out its Fibres towards the Object it flies to embrace.

15. Most, if not all, these Effects succeed in *Vacuo*, only the Light excited by *Attrition* will be of a purple Colour, in a much greater Quantity, and all within the Glass.

16. An exhausted Tube loses all its Virtue externally, which, in this Case, is wholly exerted within the Tube.

See a great Number of curious and surprizing Experiments concerning Electricity in Dr. *Priestley's* History and Present State of Electricity. 4to.

fore

fore let us now discourse of some other Properties of natural Bodies \*.

## C H A P. X.

Of TRANSPARENCY and OPACITY, DENSITY and RARITY, HARDNESS and SOFTNESS, RIGIDITY and FLEXIBILITY, in BODIES.

A. **S**IR, I thank you for your Instructions concerning *Gravity* and *Attraction*, and shall be very glad to hear you farther on the other Qualities of Bodies; and, first, what may we understand by the *Transparency* and *Opacity* of Bodies?

B. *Transparency* is that Quality of certain Bodies, whereby their Substance is enlightened, and Objects appear visible through them, as in *Glass*, *Crystal*, &c. and therefore those Bodies are called *Transparent*, *Pellucid*, or *Diaphanous*, all which Terms imply the same Thing. *Opacity* is the Quality opposite hereto; and those Bodies are said to be *Opake*, whose Matter is not *transparent*, or through which Objects are not visible.

\* Sir *Isaac's* Words are— “ Hitherto I have expounded “ the *Phænomena* of the Heavens, and of the Ocean, by the “ Power of Gravity; but the *Cause of Gravity* I have not yet “ assigned.”—Again, speaking of the Laws of Gravity, he says,— “ But the Reason of these Properties of Gravity I “ have not been able to deduce from *Phænomena*, and I frame “ no Hypotheses.—It is enough, that Gravity doth actually “ exist, and acts according to the Laws I have explained, and “ is sufficient to account for all the Motions of the heavenly “ Bodies and Sea.” *Princip. Philosophiæ, Edit. 3tia. Pag. ult.*

A. Pray



A. Pray what is the Cause of these Qualities?

B. The Cause of *Transparency* is owing to that Constitution of Bodies which admits the *Rays of Light* to pass through their Pores in right Lines; and in all Directions whatever; and, on the contrary, *Opacity* is the Effect of *Light* obstructed in its Passage through Bodies, or of that which is not transmitted in right Lines \*.

A. It seems to follow from hence, that the Matter of transparent Bodies must be very little in Proportion to their Pores.

B. Very little indeed; so little, that a celebrated Philosopher questioned whether the Quantity of Matter in *Glass* was more in Proportion to its Bulk, than one Grain of Sand to the Bulk of the whole Earth †.

A. In what Proportion are Bodies *transparent*?

\* Sir *Isaac Newton*, in the Propositions of his second Book of Optics, shews, — That the least Parts of almost all natural Bodies are in some Measure transparent, and the Opacity of those Bodies arises from the Multitude of Reflexions caused in their internal Parts. Also, that the Parts of Bodies, and their Interstices, must be of a definite Magnitude, to render them opaque and coloured; since the opaque Bodies, if their thin Parts be subtilly divided, (as *Metals* dissolved in acid Menstruums, &c.) become transparent. Again, opaque Bodies (he shews) become transparent, by filling their Pores with any Substance of equal or almost equal Density with their Parts. Thus Paper dipped in Water and Oil, the *Oculus Mundi* Stone steeped in Water, Linen Cloth oiled or varnished, and many other Substances soaked in such Liquors as will intimately pervade their little Pores, become by that Means more transparent, than otherwise. See more to the same Purpose in the same Place.

† Dr. *Keill*, in his Introduction, Lect. 5th. Page 67.

B. In

*B.* In Proportion to the *Rarity* and *Density* of Matter.

*A.* What do you call the *Rarity* and *Density* of Matter?

*B.* By *Rarity* is understood the *Thinness* of the Particles of Matter; and by *Density*, the *Thickness* thereof; in respect of the Bulk of Bodies.

*A.* Then the *Density* of Bodies hath regard both to their *Matter* and *Magnitude*, I understand by this; but what is the Proportion?

*B.* The *Densities* of two Bodies are in a Proportion compounded of the direct Proportion of their Quantities of Matter, and a reciprocal Proportion of their Magnitudes.

*A.* I believe I could better apprehend you, if you would be pleased, *Sir*, to exemplify this Matter.

*B.* I will. Thus suppose A be a Body which hath eight Parts of Matter, and five Degrees of Magnitude; and B be a Body having two Parts of Matter, and ten Degrees of Magnitude; then the *Density* of A will be to the *Density* of B, as  $\frac{8}{2} \times \frac{10}{5} = \frac{80}{10} = 8$ , that is  $= \frac{A}{B} = 8$ , or  $A : B :: 8 : 1$ ; therefore the Body A's *Density* is eight Times greater than the *Density* of the Body B\*.

*A.* What

\* 1. Let us (*Fig. LIII. of Plate VII, fronting Page 99*) illustrate this Example; and since the *Densities* of A and B are in the compound Ratio of the Quantities of Matter directly, and of their Magnitude reciprocally; it will follow,

2. That their Bulks are as directly as the Quantities of Matter compounded with the *Densities* reciprocally.

3. That the Quantities of Matter will be in the compound Ratio of the Bulks into the *Densities* directly.

A. What Means are those Qualities most of all increased or diminished by?

B. *Heat* and *Cold*; for *Heat*, by dividing, extending, and expanding the Particles of Bodies, doth attenuate and rarefy them, and this is called *Rarefaction*; on the contrary, *Cold*, by uniting and contracting the Particles of thin Bodies, doth thicken and condense them, and this is called *Condensation*.

A. Do not the Hardness and Softness of Bodies arise from their *Density* and *Rarity*?

B. No, Sir: The Hardness of Bodies ariseth from the mutual *Attraction* of the most minute primogenial Particles of Matter, whereby they firmly cohere, and are, as it were, conglutinated together: When this Firmity or Cohesion of Parts is so strong, that the Pressure of the Finger will not part or displace them, then we say such Bodies are hard; but, on the contrary, when they give way, or yield to the Touch, we call them soft Bodies.

A. What Figure of those primitive Particles of Matter is most requisite to produce Hardness or Firmity of Bodies?

B. The nearer the Figures of those Particles approach to the Figures of the five regular Bodies, or the greater their Superficies, by which they touch one another, the stronger

4. If the Bulks are equal, the Quantities of Matter in two Bodies, AB, will be directly as their Densities.

5. If the Densities are equal, their Bulks and Quantities of Matter are directly proportional.

6. If the Quantities of Matter in each be equal, the Bulks will be in a reciprocal Ratio of the Densities.

will



will be their *Attraction*; and consequently the greater their *Cohesion*, *Firmity*, or *Hardness*: But by how much less Superficies they touch, and by how much the easier they slip and slide by and over each other, by so much the softer shall we find the Bodies; and this in various Degrees even to *Liquidity* \*.

A. Is it not also to the Size, Shape, &c. of those small Particles of Matter, that the *Rigidity* and *Flexibility* of Bodies are owing?

B. No doubt of it, though it cannot be positively defined: But by the Analogy of Reason, *Rigidity* or *Stiffness* of Bodies seems to depend on two Things: *First*, an oblong Square-figured Set of Particles, which are (*secondly*) unequally placed or jointed together, as thus (—) for the Want of *Porosity* and the mutual *Attraction*, with the Resistance arising from the Position of Particles, will cause *Rigidity*; and by how much less Particles are endued with such Modifications, by so much the more Bodies are flexible or liable to bend; whence their *Flexibility* †.

\* See what has been said of the *Attraction* of *Cohesion* in Note \* in Page 103.

† See further on this Subject, *Boerhaave's* Meth. Descend. Medicinam. C. *Bartholine's* Specim. Nat. Philos. Cap. 6. *Musschenbroek's* Elements Physico-Math. Part. I. Cap. 16. *J. Clerici* Physica, Lib. V. Cap. 16, 17. *Chambers's* Dictionary, and *Harris's* Lexicon, under these Words. *Robaulti* Physica, Cap. 22; and Dr. *Clarke's* Notes, at Art. 9. *Regnault's* Phil. Convers. Vol. I. Convers. 9. with *Dale's* Notes. And the Authors mentioned in *Johnson's* Quæst. Philosophicæ, Page 13, 14, 15, 16, 17, 18.

## C H A P. XI.

Of CONSISTENCE and FLUIDITY, HEAT and COLD, HUMIDITY and SICCITY, ELASTICITY, ODOURS, and SAPOURS of BODIES.

A. **W**HAT do you mean by the *Consistence* of Bodies ?

B. That State of Bodies whereby the constituent Particles do naturally keep the same Position to each other, and are not to be moved or separated, but by some coercive external Force ; whence this Quality is also called the *Fixity* of Bodies.

A. Whence doth this *Fixity* or *Consistence* of Bodies arise ?

B. Undoubtedly from the Figure, Size, and Attraction of the constituent Particles of the same Sort with those which produce *Hardness* and *Rigidity* of Bodies.

A. Is not *Fluidity* opposite to *Consistence* ? And doth it not arise from contrary Causes ?

B. Yes : *Fluidity* is that State of natural Bodies, whereby their Particles are always in a *Flow* ; and are equally disposed to move in any Direction by the least Impression.

A. What may be the Cause of *Fluidity* ?

B. The exceeding Tenuity or Smallness, Sphericity or Roundness, Lubricity or smooth Slipperiness, and Similarity, or Likeness of the primogenial, constituent Particles of Matter : For Particles thus modified must always produce a fluid Body, or Substance, as *Water*, *Fire*, &c.

H

A. Is

*A.* Is there any Difference between *Fluidity* and *Liquidity* ?

*B.* Yes, a great deal : For *Fluidity* is a general Name for all Bodies whose Parts yield to any Impression ; and thus a Quantity of Sand as well as Water is called a *Fluid* : But what we properly call a *Liquid*, or *Liquor*, is only that Kind or Species of Fluids which *cleaveth to the Touch*, or *sticketh to the Finger*, &c. which toucheth it, and, as we may say, *wetteth* it, as doth Water, or any Kind of Juices.

*A.* What may be the Reason or Cause of this Difference ?

*B.* It is owing to the exceeding Smallness of the Particles of Liquids above those of fluid Bodies ; and also to their Weight, or Ponderosity : For, by these Means, the Particles of Liquids enter the Pores of the Body which toucheth them ; and by their Weight and Gravity, cohere to, and abide therein ; and so cause Wetness \*.

*A.* Please now to let me know, *Sir*, what your Sentiments are of *Heat* and *Cold* in Bodies, and wherein those Qualities do consist ?

*B.* *Heat* is a Sensation excited in the Mind by a great Agitation of the Particles of the hot Body, which exerteth its Action or Influence on us ; so that *Heat* in us is only the Idea thereof ; and in the hot Body, Activity or Motion, and nothing else : No *Heat* is sensible to us, unless the Motion of the Parts of a Body, which

\* The *cohesive Attraction* is herein not a little concerned, as will be easy to conceive from Note \* in Page 103.



acts on us, be greater than the Motion of the Organ or Part of the Body acted upon. When the Motion of the Parts of the Body is less than that of our Organs of Feeling, then it occasions in us the Sensation or Idea of *Cold*, or *Coldness*.

A. Then, if I take you right, *Sir*, the Reason or Difference of *Heat* and *Cold*, for Instance, in Water, lieth in this: That in the first Case, the Particles are by the Fire put into a greater Motion and Agitation than is in the Hand that feeleth it; and in the latter Case, the Motion of the aqueous Particles is in a less Degree than of those in the Hand; and thus we find it to be either *Hot* or *Cold* \*.

B. Yes, that is the true Nature of the Case, according to modern Philosophy and manifold Experiments.

A. Pray how do you conceive of *Flame*?

B. As a *Fluid*, whose Parts are ever in Mo-

\* The Motion here intended is that intestine Motion which exists among the Particles, and in the Pores of any Body, and in the Spirits, Blood and other Juices in the Organ of Feeling, to which that Body is applied.

The Heat of the Sun may be augmented to a prodigious Degree by means of a *convex* Lens or *concave* Mirrour. Thus suppose you have a double convex Lens, four Inches Diameter, and whose focal Distance is 12 Inches; it will be found by Calculation, that the *focal*, or *burning Spot* of this Lens will be  $\frac{1}{16}$  of an Inch very nearly. Now since Circles are as the Squares of their Diameters, the Density of the Sun's Rays falling on the whole Area of the Glass, will be to their Density when collected into the *focal Spot*, as the Square of 4 to the Square of  $\frac{1}{16}$ , that is, as 16 to  $\frac{1}{256}$ , or as 1600 to 1; and consequently the Heat will in that Spot be sixteen hundred Times greater than the common Heat of the Sun's Rays. No Wonder, then, they burn with such amazing Violence and *Ardor*! A *concave* Mirrour of the same Diameter, and *focal Distance*, will burn still more intensely, because many Rays are lost by Reflection on a *convex* Lens.

tion, insensible, and inconceivably great; and which seems to depend on the Air, in its natural State; because a *Candle* will not burn in *adust*, or burnt Air, as is found by Experiment.

*A.* Is not *Light* and *Fire* pretty much the same Thing, or of the same Nature?

*B.* The Particles of *Light* and *Fire* agree in several Things, *viz.* 1. In their Smallness: 2. Their Luminosity: 3. Their exceeding Activity: 4. Their Heat or burning Quality: For the Rays of the Sun, collected together by a burning Glass, burn more violently than any common Fire; kindle Wood in a Moment; immediately make *Iron* or *Steel* red hot; melt *Silver*, *Gold*, &c. in half a Minute; turn *Bones* into a *black Glass*; and *Brick*, *Tiles*, and *Earth* itself, to *green Glass* in an Instant; from whence we must infer, the Particles of *Light* and *Fire* are the same \*.

*A.* This seems a just Inference indeed: But because we cannot be large on every Head, pray give me a small Account of the Qualities called the *Humidity* and *Siccity* of Bodies?

*B.* *Humidity*, or *Moisture* of Bodies, is only a Mixture of the Particles of Liquor with those of the solid Matter of Bodies; thus Particles of

\* See concerning the Nature of *Heat*, *Fire*, *Cold*, &c. *Boerhaave's* Chymistry, Part I. Page 220, to 276; and Dr. *Shaw's* large Notes thereon. Mr. *Boyle's* History of Cold. *Cheyne's* Phil. Principles, Page 61, 62, 63. *Desaguliers's* Courses, Vol. I. Page 421, to 426. *Clare's* Mot. of Fluids, Page 225, to 229; also 287, 288. *Hales's* Veg. Statics, Page 278, 279, 280. *Clerici* Physica, Lib. V. Cap. 13. *Robaulti* Physica, Part. I. Cap. 23. Part. III. Cap. 9. cum Annot. *Clark.* annexis. *Chambers's* and *Harri's* Lexicon, under these Words. *Regnault's* Phil. Conver. Vol. I. Conv. 26; and various Numbers of the Phil. Transactions.

Water, mixed with Earth, make it *humid* and *moist*; thus the Juices of Vegetables make their Substance moist; and the Want or Defect of this Moisture, or Liquid Substance in Bodies, is what we call *Siccity* or *Dryness*; and which, in moist Bodies, is occasioned by the Sun, Fire, Wind, &c. by attenuating and rarefying the liquid Particles, and thereby causing them to fly off in *Steam*, or insensible *Vapour*.

*A.* In the next Place, pray, *Sir*, tell me what that Property is in Bodies which you call *Elasticity*?

*B.* It is that Disposition of some Bodies, whereby, when the Parts of the Body by Pressure are put out of their Place and Form, they immediately again return to, or recover their first Position and Figure.

*A.* Whence doth this Property proceed?

*B.* It is hard to say what are the particular Circumstances of the Cause of *Elasticity*; however, it is certainly owing to the special Figure, Surfaces, and Attraction of the Parts of elastic Bodies.

*A.* Are all Bodies elastic?

*B.* Yes, in a greater or lesser Degree; but none are perfectly elastic.

*A.* Pray what do you call perfect *Elasticity*?

*B.* That, whereby a Body recovers its Figure by the same Force it lost it.

*A.* Is there any Thing remarkable in the Motion of Bodies derived from their *Elasticity*?

*B.* Yes: If an elastic Body *A* strikes against the firm Bottom *CD*, obliquely in the Direction *AF*, it will always rebound again in the same Obliquity *FE*, or so, that the Angle



EFD shall always be equal to the Angle AFC. See *Fig. XVII. of Plate VIII, fronting p. 120.* Besides this, there are many other Properties of the Motion of springy or elastic Bodies, arising from their *Spring* or *Elasticity*; for which larger Volumes must be consulted \*.

A. Well

\* In the Percussion or Striking of Bodies not elastic, there are four Cases, *viz.*

1. If one Body strikes against another at Rest, they will both move together in the Direction of the first Motion; and the Quantity of Motion in the two Bodies will be the same as in the single one before the Stroke.

2. If one Body strikes another moving the same Way, but slower, they will both continue their Motion in the same Direction as before; and the Quantity of Motion in both will still be the same.

3. When two Bodies with equal Quantities of Motion tend both directly towards, and strike each other, the whole Motion will be destroyed by their Meeting, and the Bodies will be at Rest.

4. Two Bodies moving both directly towards each other with different Velocities, after the Stroke, will both continue their Motion in the Direction of that Motion which had the greatest Velocity; and the Quantity of Motion after the Stroke is equal to the *Difference* of their Motions before it.

In *elastic Bodies*, other Rules obtain: Suppose two such Bodies A and B; let A have three Parts of Matter, and eight Degrees of Velocity; and B have nine Parts of Matter, and two Degrees of Velocity: Then, the Quantity of Motion in A will be 24, and that of B 18. Now supposing these Bodies to impinge on each other, the *Velocity* of each after Impact, and the *Direction* of their Motions, may be known as follows:

1. Let the Body A impinge on B at Rest; then from A take B, and multiply the Remainder by the Velocity of A; divide this Product by the Sum of the Bodies A and B, the Quotient will express the Velocity of A after the Stroke. As the Body A is less, equal to, or greater than B; so it will be retrograde, or direct in Motion after Impact. Thus, in the present Case, the Difference of A and B is 6, which multiply by A's Velocity 8, the Product is 48; this divided by the Sum of the Bodies 12, quotes 4, the Degrees of Velocity with which A will return back after Impact.

2. Again, divide twice A's Motion by the Sum of the Bodies, the Quotient will be the Velocity of B after Impact. Thus 48 divided by 12 quotes 4, the Velocity of B after the Stroke. So that,

A. Well then, leaving that, let us proceed to what you call the *Odours* of Bodies; pray what are they, or wherein do they consist?

B. The *Odours* of Bodies, by affecting the Organ of Smelling, *viz.* the Nose, do raise and excite in us the Sensation we call *Smell*, or *Scent*:

tho' the Velocity be the same, the Motion in both Bodies is double to what it was at first in A.

3. Let the Bodies both tend one Way, and A follow B; then, to the Motion of A add twice the Motion of B, from that Sum subduct the Product of A's Velocity multiplied into the Matter B; divide the Remainder by the Sum of the Bodies, the Quotient will be the Velocity of A after Impact. As the *Product* is *lesser*, *equal* to, or *greater* than the *Sum* (above mentioned) so the Motion of A will be *direct*, *none at all*, or *backward* after the Stroke.

4. Again, to twice the Motion of A add the Motion of B, from that Sum subtraet the Product of B's Velocity into A; divide the Remainder by the Sum of the Bodies, the Quotient will be the Velocity of B after the Impact.

5. An Example of each, in our present Case, is as follows: To 24 add 36, the Sum is 60, which I take from 72, (as being greatest) the Remainder is 12, which I divide by 12, the Quotient is 1; so that A returns back with *one* Degree of Velocity, having lost *seven*.

6. Again, to 8 add 58, the Sum is 66, from which I take 6; the Remainder 60 I divide by 12, which quotes 5 for the Velocity of B's Motion.

7. If the Bodies tend the contrary Way, or meet; then, from the Sum of twice B's Motion, and the Product of A's Velocity into B, take the Motion of A, and divide the Remainder by the Sum of the Bodies, the Quotient is A's Velocity after meeting; and as that Sum is greater, equal to, or less than the said Motion of A, the Motion of A will be backward, none at all, or forward.

8. Again, to the Difference of B's Motion and twice A's, add the Product of B's Velocity into A; divide the Sum by the Sum of the Bodies, the Quotient will be the Velocity of B after Reflection.

9. To illustrate both these Cases by our present Example. The Sum of 72 and 36 is 108, from which I take 24; the Remainder 84 I divide by 12, which quotes 7 for A's Velocity backward. *2dly.* To the Difference of 48 and 18, which is 30, I add 6, and divide the Sum 36 by 12, the Quotient is 3 for B's Velocity the contrary Way.

10. These Rules are applicable to all Bodies, and Celerities; and whosoever will, may see their Investigation in *Keill's* Introduction, *Lecture* 14. *Theor.* 29. *Prob.* 3.

These *Odours* of Bodies are nothing but *Effluvia*, or exceeding fine and insensible Particles, flying off the *odoriferous* Bodies in all Directions; and as they float in the Air, strike against, and cause in our Nostrils the aforesaid Sensation of Smell.

*A.* In what Degree or Proportion are those *Effluvia*, or *Odours*, sensible to us?

*B.* The Sensation which they excite in us, or the Degree or Intensity of Smell, is always in Proportion to their *Density* or *Thickness* where we are; and this *Density* always decreases in Proportion to the Squares of the Distance from the *odorous* Bodies.

*A.* Pray, *Sir*, can you not make this somewhat more evident and plain by Example?

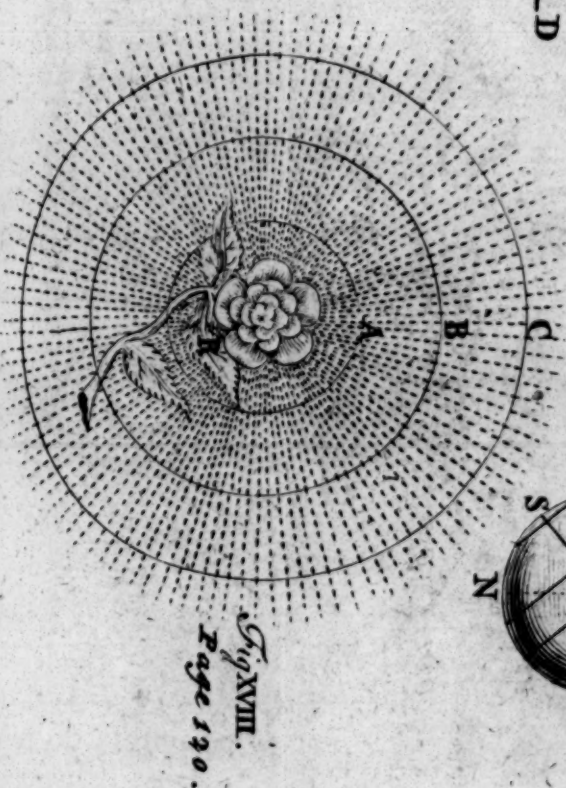
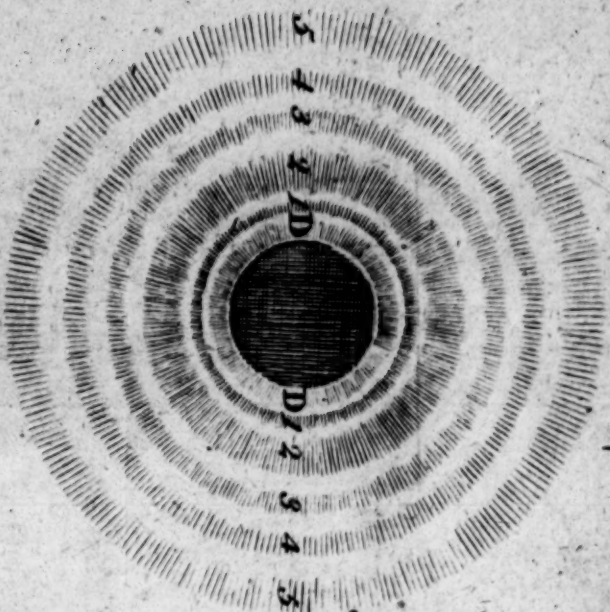
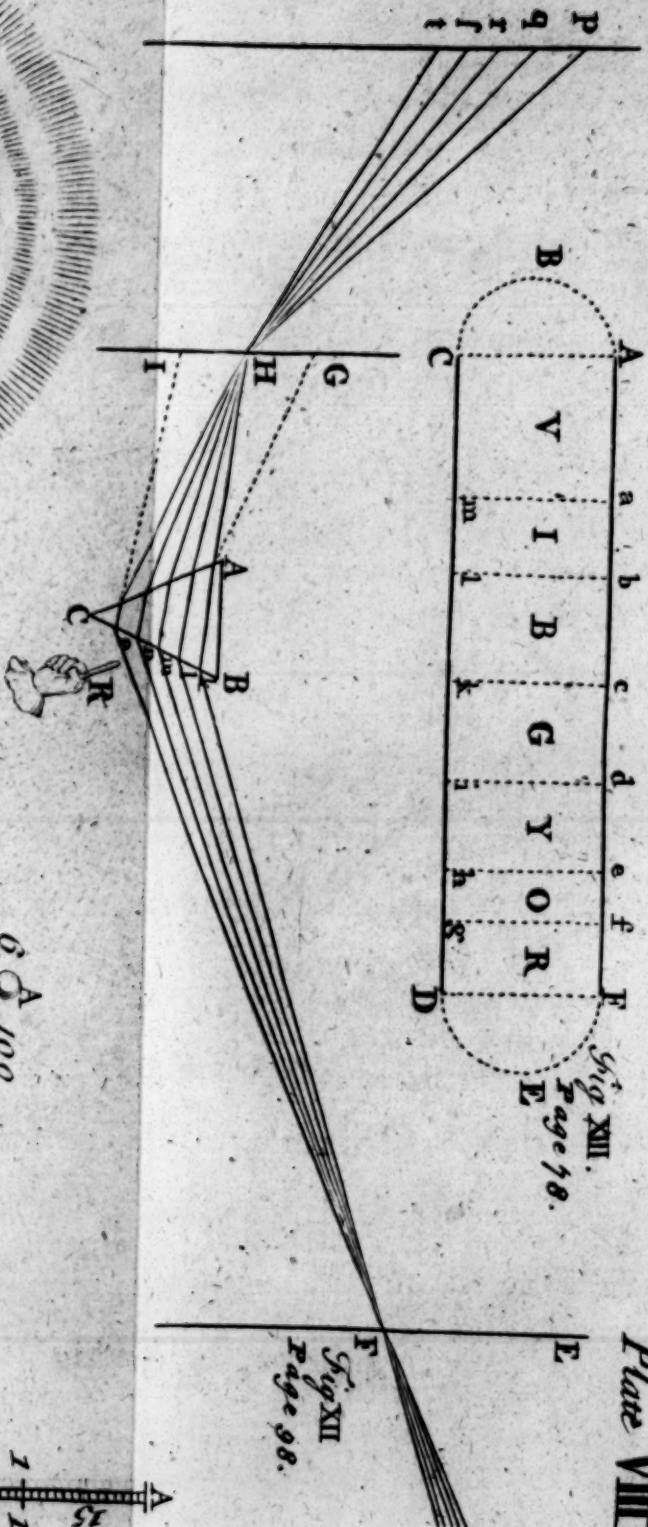
*B.* Yes: Let *R* represent a Rose, and the Dots about it the Emanations of numberless *Effluvia* of *Odours*; now suppose the Nose in three several Distances at *A*, *B*, and *C*, which let be 1, 2, and 3 Feet from the Center of the Rose: Now, I say, the Degree or Intensity of Smell, at those Distances, will decrease in Proportion to the Squares thereof, 1, 4, 9, *i. e.* it will be four Times less at *B* than at *A*; and nine Times less at *C* than at *A*. Do you apprehend it now? See *Fig. XVIII. of Plate VIII, fronting p. 120.*

*A.* Very well, *Sir*, and am obliged to you: But, pray, how comes it about that some irrational Animals, especially some Dogs, can smell any Thing at so much greater Distance than we can?

*B.* This is entirely owing to the greater Perfection of that Organ in those Creatures than in Man, as being on many Accounts more necessary

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in them than in us ; for in them, God has made it *one Means to preserve Life* ; in us he seems to have designed little more than *Gratification and Pleasure* thereby.

A. Whence do *Sapours* or *Tastes* of Bodies arise ?

B. From a certain determinate Magnitude and Figure of the Particles of the *saporific* Body, which, in the Make of the Tongue, do thereby occasion the Sense of *Taste* in all Varieties, according to the different Modification and Configuration of those *saporiferous* Particles.

A. But what are those Sizes and Figures of Particles necessary to qualify them to exert this *saporific* Virtue, which you speak of ?

B. No Man knows that ; we should be contented to have a general Knowledge, when Particulars are denied us ; we had better confess our Ignorance in Naturals, and adore the superlative Wisdom of God, who hath made it his own Prerogative to know all Things ; than feign vain or absurd Hypotheses, with an ambitious and impious View of being thought omniscient, or able to account for all Things \*.

A. I think so too indeed, *Sir*, and ask Pardon for being sometimes too curiously inquisitive about the *Arcana* of Nature.

B. *Sir*, we are allowed, yea, it is our Duty, to improve our Knowledge, and communicate

\* For a more particular Account of *Odoriferous Effluvia*, and the wonderful Sagacity of Dogs, &c. in respect of this Sense, see *Boyle on Effluvia*, Chap. 4. Also for *Taste*, and the Causes and vast Diversity of *Tastes*, read Dr. *Grew's Anat. of Plants*, and the Treatises referred to in Note † in Page 112, and Note \* in Page 116.



the same to each other so far as we are capable:  
And having taken this particular Survey of the  
Properties and Qualities of Bodies, let us pro-  
ceed to a general View of the Universe com-  
posed thereof.

## C H A P. XII.

*Of Sir ISAAC NEWTON's Laws of Nature.*

B. **B**UT before we launch out into the  
boundless Extension of the Universe,  
where we shall see every Thing in Motion all  
about us, it will be proper previously to con-  
sider that (though we have already seen the  
general Properties and *Phænomena* of Motion,  
yet) there are some stated certain *Rules*, or *Laws*,  
by which all the Motions of all natural Bodies  
are constantly governed and determined, and  
by which every Thing relating to Motion may  
be explained.

A. How many are those *Laws*?

B. Sir *Isaac Newton* has laid down three.

A. But, pray, if you please, tell me why they  
are called Sir *Isaac Newton's Laws of Nature*?

B. That is more than I can do: Sir *Isaac*  
was not the first Inventor of them, since, if  
you please, you may see them in Monsieur  
*Des Cartes's* Philosophy, which was known  
before Sir *Isaac's* appeared \*.

A. Pray what are those *Laws*?

B. The *First* is this:

\* See *Des Cartes Principia Philosophiæ*, Part. II. Pag. 38, 39,  
40.

L A W I.

*All Bodies continue in their State of Rest, or Motion, uniformly in a right Line, excepting they are obliged to change that Estate by Forces impressed.*

A. What is the Foundation of this Law?

B. We see all Bodies, by their Nature, are inactive and incapable of moving themselves; wherefore, unless they be moved by some external Agent, they must necessarily remain for ever at Rest.

A. But why must a Body in Motion, if left to itself, for ever so continue in a right-lined Course?

B. We know this by daily Experience; for when any Body is put into Motion, it continues to move in the same rectilinear Direction, and with the same Velocity; until the Resistance of the Air, the Power of its own Gravity, the Make of the Body, or some other external Cause, determines it from a right-lined Direction, diminishes its Velocity, and brings it at last to a State of Rest \*.

A. If this be the Case, pray how comes it to pass that the *Sun, Moon, Comets, &c.* continue their Motion so long; have the Regions, thro' which they move, no Resistance?

\* Motion, when once produced in any Body, can never be impeded, diminished, or destroyed, but from something within or without the Body. Now all Experience testifies, that Matter is in itself inert, and powerless, and so absolutely so, that it can in no wise be considered as the Cause of any Thing either within or without itself; consequently, whatever retards or destroys Motion must be something external to the Body moved; but in a perfect *Vacuum* there is nothing of any Kind, therefore in such a Case Motion must of Necessity be perpetual.

B. The

*B.* The Bodies of the *Planets* and *Comets* are vastly great; and the Spaces, thro' which they move, have small Resistance, by which Means they conserve their Motions the longer.

*A.* Pray what is the next *Law* of *Nature*?

*B.* The *Second Law* is this;

## L A W II.

*All Change of Motion is proportional to the Power of the moving Force impressed; and is always made according to the Right Line in which that Force is impressed.*

*A.* What do you observe from thence?

*B.* That if any Power produceth any Motion; another Power, which is double, triple, &c. will produce a double, triple, &c. Quantity of Motion; whether it be impressed together, and at once, or successively by Degrees: And this Motion (because it is ever determined towards the same Part with the generating Force) is added to the Motion of a Body in the same Direction by Impact, and it will move so much the quicker; but it is subtracted from the Motion of a Body in contrary Direction, and therefore that Body will move so much the slower. It is also obliquely joined to the Motion of a Body obliquely moving; and will be compounded with it according to the Determination of both. Hence a very considerable Consequence will follow.

*A.* Pray what is that?

*B.* Why, according to the present Constitution of Things, it follows from this *Law*, there can be no perpetual Motion; for by this *Law*,  
the



the Motion produced is but proportional to the generating Force; and all Motions on this Globe being performed in a resisting Medium, *viz.* the Air, a considerable Quantity of the Motion must, in the Communication, be spent on this Medium; and consequently it is impossible the same Quantity should return undiminished upon the first Mover, which yet is necessary towards a perpetual Motion: Besides, that such a Diminution of Motion will be greatly increased by the constant Friction of the Parts of the Machine; for there will be more or less of that, be the Instrument ever so well contrived, there being no such Thing as absolute Smoothness or perfect Congruity, in Nature; at least, not in any of the Works of Man \*.

A. Pray what is the *third Law*?

B. This:

L A W III.

*Repulse, or Re-action, is always equal, and in contrary Direction to Impulse or Action; i. e. the Action of two Bodies upon each other is always equal, and in contrary Directions.*

A. Can you illustrate this Matter a little by a familiar Instance or two?

B. Yes: Thus, if you press a Stone with your Finger downward, the Stone equally presses your Finger again upward: If a Horse draw

\* Concerning a perpetual Motion, the Machine contrived for that Purpose, and the Reasons and Arguments which evince the Impossibility thereof, see *Desaguliers's Course*, Vol. I. Page 175, to 178. *Cheyne's Philos. Principles*, Page 16, 17; and *Chambers's Dictionary* at the Word: With several other Authors.  
for-

forward a Stone tied to a Rope, the Stone equally draws back the Horse ; for the Rope being equally distended both Ways, acts on both Horse and Stone equally. The Anvil strikes the Sledge with the same Force the Sledge strikes it, which therefore rebounds or flies back. The Steel draws the Magnet, as much as the Magnet draws the Steel ; as is evident by making both swim in Water. When a Barge is pulled to the Bank by a Rope, the Bank pulls the Barge as much as the Bargeman pulls the Bank : And in the Descent of heavy Bodies, the Stone that falls attracts the Earth as much as the Earth attracts it ; that is, the Motion of the Earth is equal and contrary to that of the Stone.

*A.* Why these are all *Paradoxes* surely ; I cannot conceive how it can be, nor believe that the Earth moves as much towards the Stone, as the Stone does towards it in falling.

*B.* But it is true, and is what I proved to you, if you remember, when we discoursed of the *Gravitation* of Bodies towards each other. I there shewed, the Reason we cannot see such a Motion of the Earth, is because of the incomprehensible Disparity of the Velocities of the Stone and the Earth : For, as I shewed you on the Subject of the Motion of Bodies, the *Motions of any two Bodies may be equal to each other, when the Velocities of their Motions are infinitely different.*

*A.* It is true, I remember you did so ; and I find what creates the Wonder, is only a Mistaking of *Velocity* for *Motion*, which is an entire different Thing.

*B.* Yes,

B. Yes, it is so; and in most Cases, were the true Nature and Differences of Things well attended to, we should not be so liable to inglorious Wonder and Astonishment (the constant Effect of Ignorance) as we too commonly are. On this third *Law* depends all the Doctrine of the Loss and Gain of Motion in Bodies impinging on each other, according to Note \* in Page 118. But now let us extend our View over the *universal Space* †.

† See the Laws of Nature explained more abundantly at large in Sir *I. Newton's* Princip. Pag. 13, & seqq. *Graves's* Elem. Matth. Book I. Chap. 12. *Keill's* Introd. to Nat. Philos. Lect. XI, XII. *Desaguliers's* Course of Exp. Philos. Lect. V. and Annot. thereon. *Domkii* Philos. *Newton* Tom. II. Pag. 15. &c. *Cheyne's* Philosoph. Principles, Page 7 to 24. *Worster's* Philos. Page 45. *Webster's* Prin. of Nat. Phil. from Page 45 to 110; and various Writers on *Mechanics*.





THE  
*Philosophical Grammar:*  
Or, VIEW of  
Modern Philosophy.

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PART II.

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COSMOLOGY:

CONTAINING,

- I. A general View of the *Universe*.
- II. The Philosophy of the *Sun*.
- III. The Philosophy of the *Moon*.
- IV. The Philosophy of the *Planets*.
- V. The Philosophy of the *Comets*.
- VI. The Philosophy of the *fixed Stars*.

Explaining their *Nature, Properties, and Affections*, so far as  
they are at present known and understood.

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CHAP. I.

*Of Cosmology in general, of the mundane Space,  
of a Vacuum, of Duration or Time.*

A. **W**HY do you call the second grand  
Division of the Science of Nature  
*Cosmology*?

B. On Account of the Propriety of the  
original Sense of the Word, and its Congruity  
with the Things which are the Subjects of the  
Science intended thereby.

A. What is originally imported by the Word *Cosmology*?

B. It is composed of the two *Greek* Words, κόσμος, the *World*, and λόγος, a *Discourse*; and therefore, by *Cosmology*, is implied a philosophical or physiological *Discourse* of the *World*, or *Universe* in general.

A. In what Manner, or Order, then, do you design to proceed in taking this general View, or Survey of the *Universe*?

B. In the *first* Place, to observe the Order and Constitution of it, so far as it is known, with the several Parts thereof great and small. *Secondly*, we will take some Notice of the Mundane Space; in which the various Parts or Bodies of the *Universe* do consist, and are posited here and there. *Thirdly*, we shall discourse a little of the Nature of *Duration* or *Time*, whereby the Motions of all the Bodies in the *Universe* are measured.

A. This will be very delightful indeed; pray make a Beginning. What do you first observe in the general Constitution or Frame?

B. The first great *Phænomenon* of the *Universe*, which more eminently strikes our Senses, is that glorious Luminary we call the *Sun*, the Source of *Light*, and Center of our *Planetary System*, or about which the *Chorus* of all the *Planets* move.

A. What, do you suppose the *Sun* to be the Center of the *Planets* Motion, and not a moving *Planet* itself?

B. Yes; the *Sun* is in the Center of our System, around which the primary *Planets* move. See Fig. XIX. of Plate X, fronting p. 134.

*A.* Pray which, and how many are those you call primary *Planets*?

*B.* They are in Number six; and their Names are, *Mercury*, *Venus*, the *Earth*, *Mars*, *Jupiter*, and *Saturn*; these, in different stated Periods of Time, all revolve about the *Sun*, in the Order I have rehearsed their Names.

*A.* But, pray, what becomes of the *Moon*, that you mention her not amongst the *Planets*? And how came you to make a *Planet* of this *Earth* in her stead?

*B.* I am taught by the modern *Physiology* so to do; it is very certain the *Earth* is a *Planet*, and moves about the *Sun* with the rest: And as to the *Moon*, I do not say she is not a *Planet*, but not a primary or principal one.

*A.* Why, *Sir*, what Difference do you make in the Kind of *Planets*?

*B.* There is discovered a two-fold Kind of *Planets*, viz. There are some very great and large ones, which regard the *Sun* as the Center of their Motions; these are called *primary Planets*, and are those before named: Again, there are other lesser ones, called *Satellites*, or *Attendants*, which circulate round some *primary Planet*, as their Center; and these are termed *secondary Planets*; and such a one is the *Moon* \*.

\* The Word *Satelles* is *Latin*, and with the *Romans* signified an *Officer*, *Serjeant*, or *Yeoman* of the Guard of a Prince, whose Office was to attend and defend his Person; whence the *Astronomers*, by an easy Metaphor, call a *Moon* (which constantly attends its proper Planet in all his Revolutions about the *Sun*) a *Satelles*, and, if there be more than one, *Satellites*, which is a four-syllable Word, viz. *Sa-tel-li-tes*, and not a three-syllable one, as it is vulgarly, though viciously pronounced.



A. Sure it will be thought very strange, that the *Moon* (which, next to the *Sun*, is the greatest Luminary in the Heavens) should be esteemed only as a small secondary *Planet*; the *Moon* is little obliged to your new Philosophy, being thus degraded from her ancient shining Post amongst the primary ones!

B. What I say on this Head is founded on Reason, Observations, and Experiments; and therefore claims Belief before those Notions which depend only on vulgar Sense, and were the Products of a most rude and barbarous Age, though ever so glaring: Remember, *all is not Gold that glisters.*

A. Well, I am glad to meet with Truth, whatever I exchange for it: But what do you next observe in this wonderful *Frame*?

B. The amazing Bodies we call *Comets*; which make such prodigious Excursions into the unknown distant Regions of the *Universe*, as to take up (some of them) several hundred Years in making one Revolution about the *Sun*.

A. I suppose, by *Comets* you mean blazing *Stars*; and do they likewise move about the *Sun*?

B. Yes; but in Orbits vastly eccentric, and approaching nearer to the Form of a *Parabola*, than an *Ellipsis* or *Circle*.

A. Well, what next to these offer for the Subject of our Contemplation, in this universal Scene?

B. The fixed Stars, which enamel and bespangle the concave Expanse, or Canopy of Heaven; which, by their Numbers and Lustre, make the Night beauteous and delightful, which

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would be otherwise dark and horrible : And thus I have rehearsed to you all the great Parts of which the World doth consist, so far as we know any Thing of it \*.

\* The *System of the World* now described, is not a late Invention, but was known and taught by the wise *Samian Pythagoras*, and others among the Ancients, which in after Times was lost; 'till in the 15th Century it was again revived by the famous Polish Philosopher, *Nicholas Copernicus*, who was born at *Tborn* in the Year 1473. In this he was followed by the greatest *Mathematicians* and *Philosophers* that have since lived, as *Kepler*, *Galileo*, *Descartes*, *Gassendus*, and Sir *Isaac Newton*, who has established this System on such an everlasting Foundation of Mathematical and Physical Demonstration, that neither the Gates of Ignorance, nor the Power of Popish *Anathema's*, shall ever prevail against it.

The most famous of the antiquated Systems are two, *viz.* One taught by *Ptolemy*, the *Egyptian Astronomer*, said to have lived 138 Years before Christ. The other by the noble Dane, *Tycho Brahe*, born in *Schonen*, A. D. 1546.

The *PTOLEMEAN SYSTEM* (*Fig. XLIV. on Plate IX, fronting p. 132.*) supposed the Earth immoveably fixed in the Center of the World, about which moved seven Planets, *viz.* the Moon, *Mercury*, *Venus*, the Sun, *Mars*, *Jupiter*, and *Saturn*; above these is placed the *Firmament* of the fixed Stars, then the two *CrySTALLINE Spheres*; all which were included in, and received Motion from, the *Primum Mobile*, which constantly revolved about the Earth in 24 Hours from East to West. But this rude Scheme was too much accommodated to Sense, to stand the Test of Art; the *Mathematicians* soon perceived it a Medley of the grossest Errors and Absurdities, which they rejecting (as fit only for the Ignorant, and zealous Bigot) chose other more rational Methods to pursue the grand Discovery.

The *TYCHONIAN SYSTEM* succeeded the *Ptolemean*, but was never so universal. This supposed the Earth in the Center of the World, (see *Fig. XLV. on Plate IV, fronting p. 132.*) or *Firmament* of fixed Stars, as also of the two Luminaries, the Moon and the Sun. But then he supposes the Sun the Center of the Planetary Motions, *viz.* of *Mercury*, *Venus*, *Mars*, *Jupiter*, and *Saturn*; these, with the Sun, all revolved about the Earth in the Space of a Year, to account for the *annual Motion*; and the Earth he made to revolve about the Axis every 24 Hours from West to East, to solve the *diurnal Motion* of the Heavenly Bodies from East to West. This *Hypothesis* being partly true, and partly false, and imbarassed with many Difficulties and Absurdities, was embraced by few, and soon gave way to the only true and rational *Solar System*, restored by *Copernicus*, as aforesaid.

A. Pray



Fig. XLIV

Page 132.

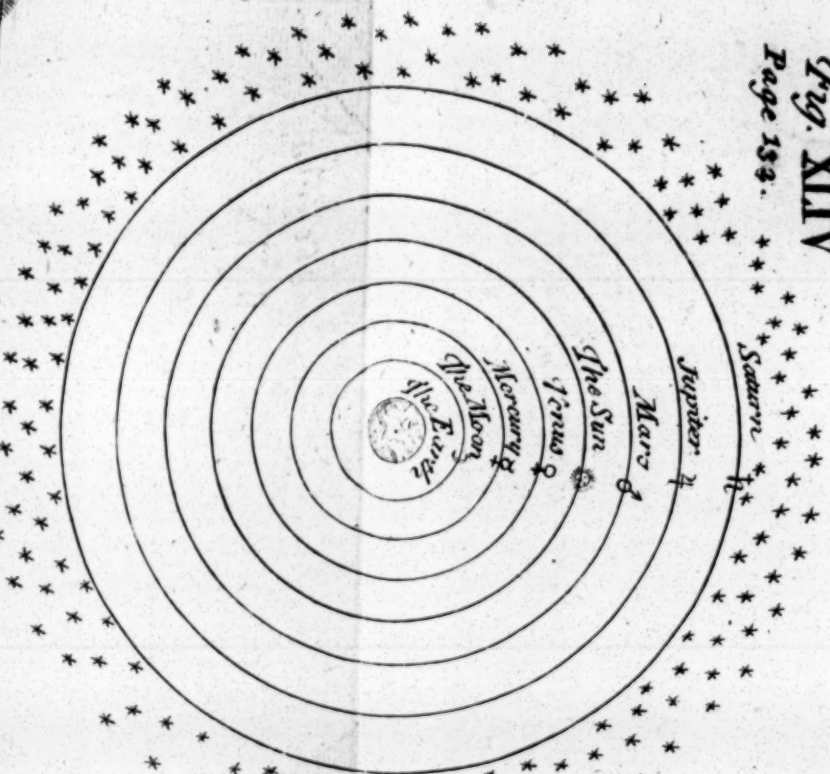


Fig. XLV

Page 134.

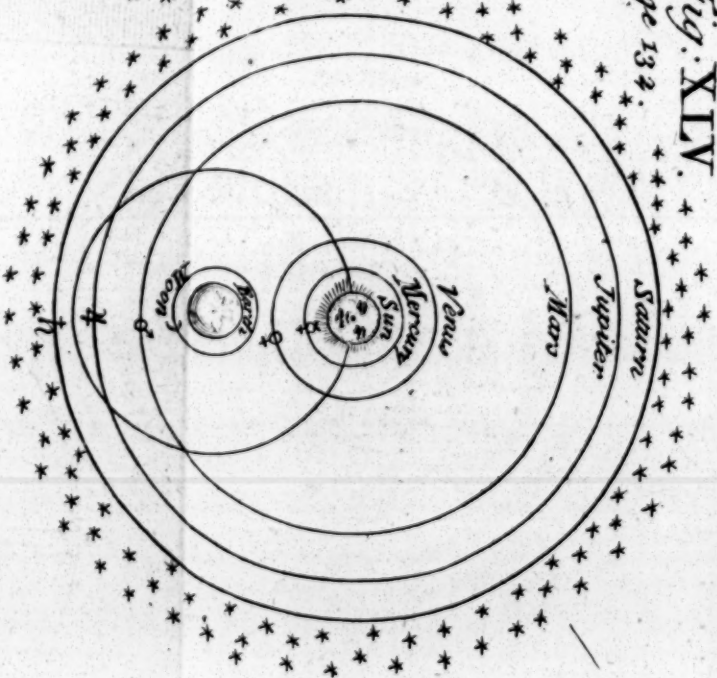


Fig. XLVI

Page 136.



Fig. XLVIII

Page 144.

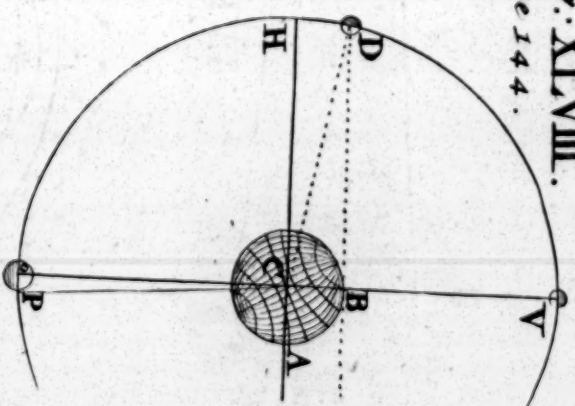
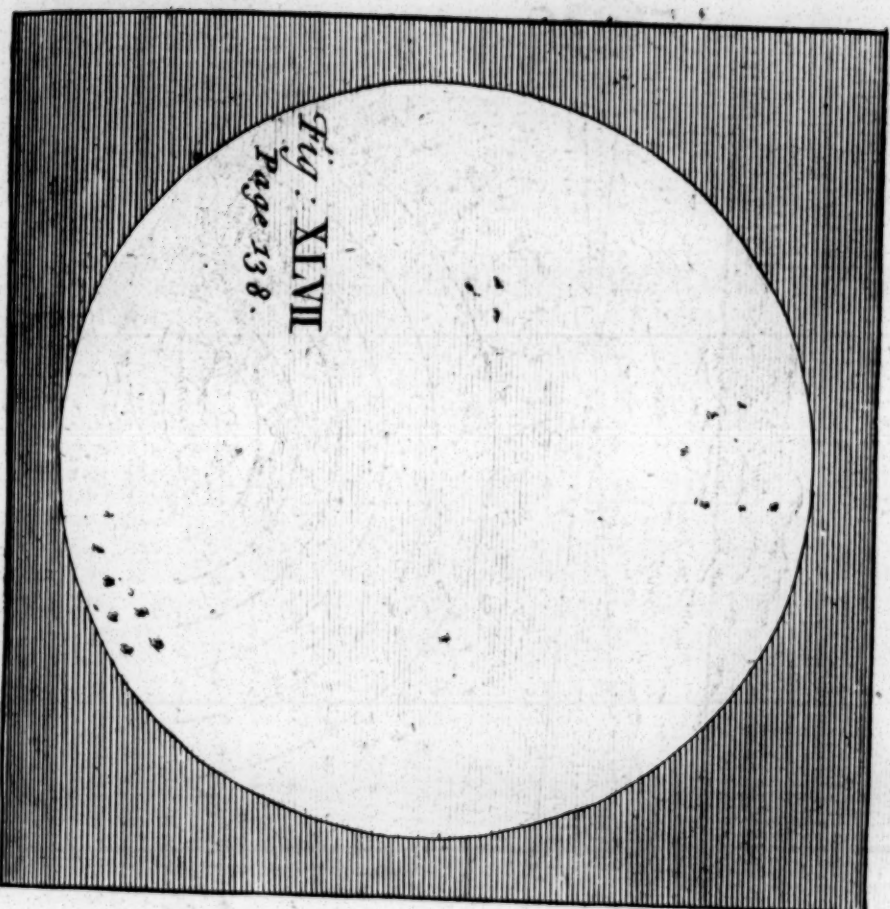
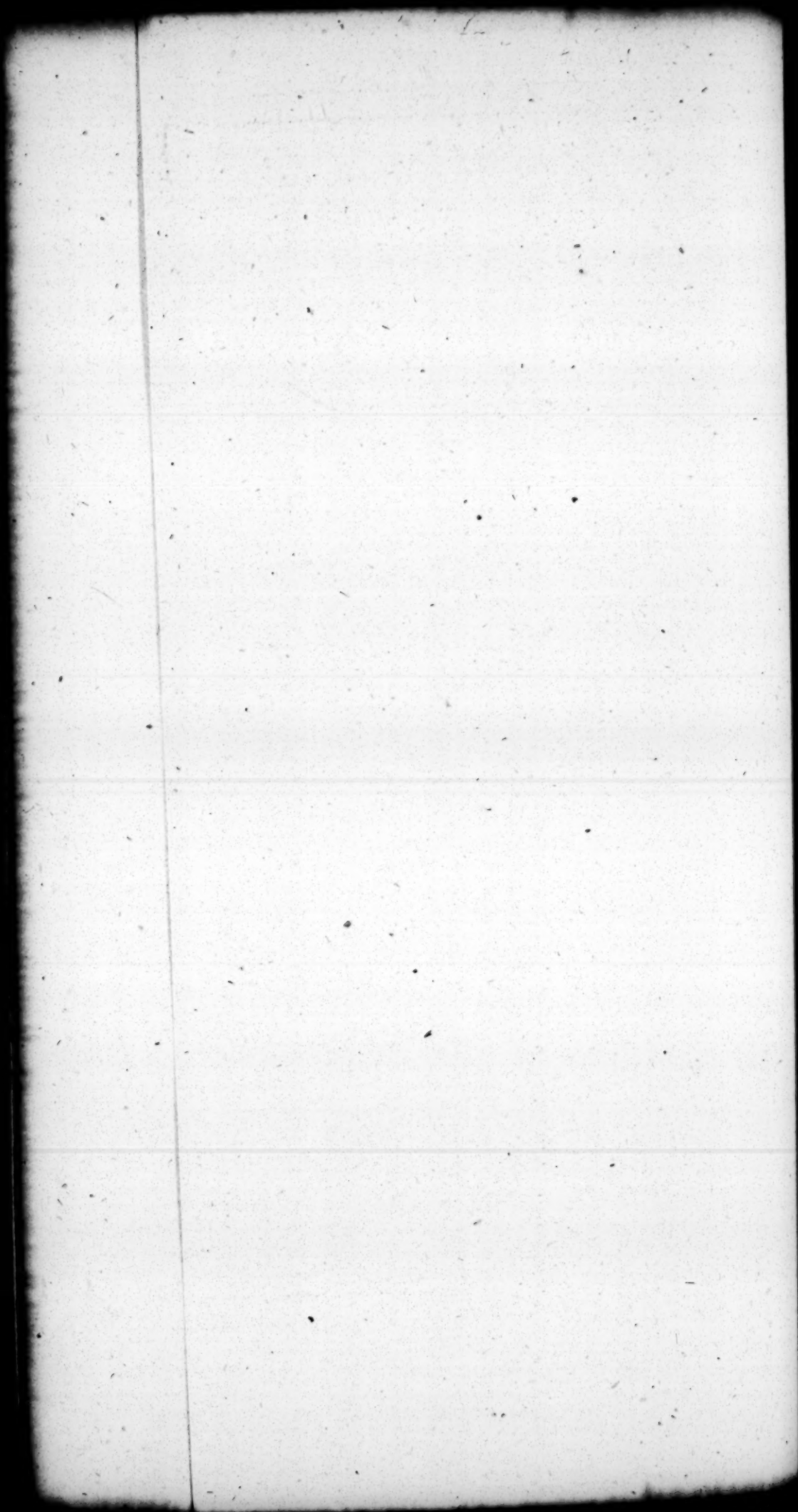


Fig. XLVII

Page 138.







*The Constit. and Parts of the Universe.* 133

A. Pray what is the Form or Figure of the *Universe*?

B. It hath no determinate Form or Figure at all; forasmuch as it is every Way infinite and unlimited.

A. What do you call the *mundane Space*?

B. The infinite *Space*, in which all Bodies of the *Universe* have their Place and Being.

A. Pray what do you properly call *Space*?

B. Extension without Matter; or, in plain English, a perfect *Void*, or *Vacuity*; which is better conceived than defined \*.

A. What is that the Philosophers call a *Vacuum*?

B. A *Vacuum* is a perfect *Void*, or *Space* absolutely devoid of all Body or Matter; as, on the contrary, they call that a *Plenum*, when any Part of *Space* is so absolutely filled with Matter, as to have no *Vacuities* therein.

A. Is there any such Thing as a *Vacuum* in Nature?

B. Yes; only those who denied their Reason, have denied this.

A. How do you prove a *Vacuum*?

B. A thousand Ways almost; but Motion evinceth it most plainly; for can any one suppose a Body to move in the Midst of *Solidity*?

\* See Dr. *Watts's Enquiry concerning Space*, Phil. Essay I. Mr. *Locke*, in his *Human Understanding*, confesses he does not know what it is, nor to what Class of Beings to refer it, *Hum. Und.* Book II. Chap. 13. § 17. Sir *I. Newton* considers *Space* as the *Sensorium* of the Divine Mind, *Prin. Math. Philos.* Page 528. *Optics*, 2d Edit. Page 379. The *Cartesians* absurdly pretend it is a Body or Substance. And others deny that it has any real Existence. See the Authors mentioned in *Johnson's Quæst. Philos.* Page 169, 170.

They who affirm this, may as rationally affirm, that a Bird may fly through a Mountain of *Adamant*, as easily as through the open *Air* : And who so blind as not to see the most monstrous Absurdity thereof by this one Argument \* ?

*A.* I think none can deny it indeed, who would be thought rational : But, pray, what have you to say of *Duration* or *Time* ?

*B.* *Duration* is the Idea we have of the Continuance of the Existence, or Being of Things; and in order to estimate and measure the Parts thereof, we use the Motions of moving Bodies, as the Sun, Stars, a Clock, &c. and the Parts of *Duration* thus compared and measured, we call Time, Times, Seasons, Ages †, &c.

## C H A P. II.

*Of Uranology, or the Doctrine of the heavenly Bodies ; and first of Heliography, or the Philosophy of the Sun.*

*A.* **W**HAT is the Meaning of the Word *Uranology* ?

\* It is an old Maxim, that nothing is more difficult than to prove the Truth of a self-evident *Axiom*, or that which is obvious to the common Sense of all Mankind. This is sufficiently confirmed by the numerous Controversies on the Subjects of *Space* and a *Vacuum* ; for though nothing is more evident than the Nature of the one, and the Certainty of the other, yet nothing has more distracted and perplexed the Minds of Philosophers, as may be easily seen by perusing the Authors on these Subjects referred to in *Johnson's Phil. Questions*, Page 9.

† The Doctrine of *Time* is the Subject of *Chronology* ; an Abstract of which excellent Science the Reader may find in my *Philological Library of Literary Arts and Sciences*.

*B.* It



# The Copernican or Solar System .

Page 134

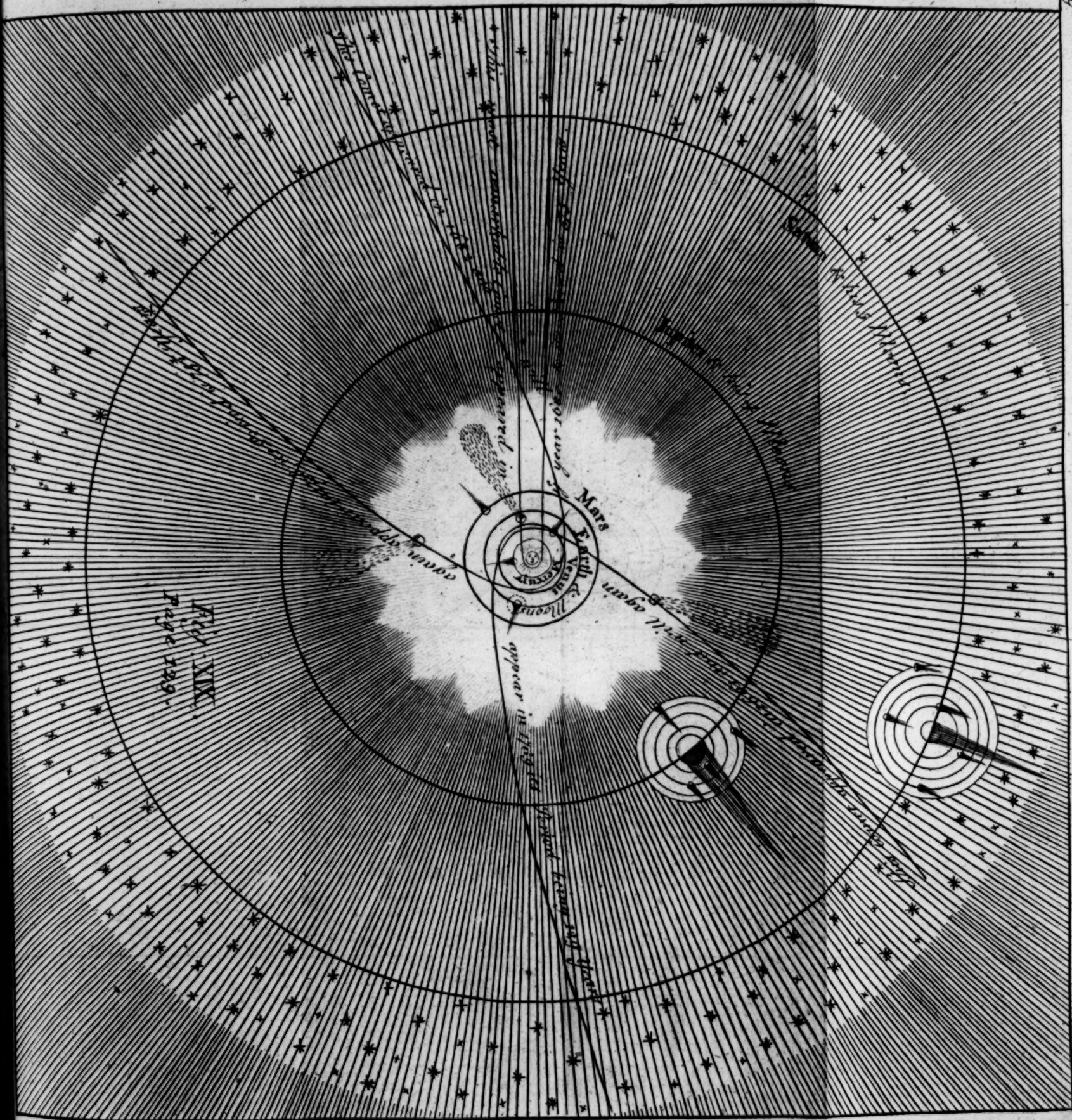


Fig. XIX.  
Page 129.

Plate X

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*Of the Sun, his Bulk, Density, &c.* 135

B. It is of Greek Original, and is composed of οὐρανός, *Heaven*, and λόγος, a *Discourse*; therefore it signifies a *Discourse* or *Treatise* of the *Heavens*, or *heavenly Regions*, and *Bodies* therein.

A. Pray what do you call the *Heavens*, or *heavenly Regions*?

B. Those *Regions*, or *Fields*, of *Æther*, which lie all around us above the *Atmosphere*; in which are situated all the shining *Bodies*, the *Sun*, *Planets*, *Comets*, and *Stars*, and wherein they perform all their *Motions*.

A. Where will it be proper for us to begin our *Conversations* on these celestial *Subjects*?

B. We will first begin with *Heliography*, if you please.

A. I do not understand the proper *Meaning* of that *Word*, please therefore to unfold it.

B. By *Heliography* (as being composed of ἥλιος, the *Sun*, and γραφή, a *Description*) is to be understood, a *philosophical Description* of the *Sun*.

A. Well, it seems very congruous to begin with what you make the *Center* of our *System* as you call it; and pray what do you first observe of the *Sun*?

B. The *Sun* is a huge *Body* of *Light*, or *Fire*, whence all the other *Planets* receive their *Light*; and by whose *Emanations* of *Rays*, and *Beams* of *Light*, the whole *System* of *Beings* about us is illuminated and made visible.

A. Can you tell any *Thing* of the *Sun's Bulk*?

B. Yes: The *Diameter* of the *Sun* is computed at 822148 *English Miles*; and its *Bulk*, or *solid Content*, at 290971000000000000 *Miles*;



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which is about 1000000, or a Million of Times greater than the Globe of our Earth \*.

A. Stupendous Magnitude! And what, do you suppose it to be all Fire?

B. Yes; and therefore some have thought it to be the Place of Hell †: However, its Quantity of Matter is well known; and the Density thereof is very considerable.

\* 1. To compute the Diameter of the Sun, his Distance from the Earth must first be known, which supposing his *horizontal Parallax* 10 Seconds, I have found to be 82136014 Miles, in my *Young Trigonometer's Guide*, Vol. I. Part 2. Chap. 3. § 14.

2. Suppose then you have a double convex Lens, as L, (*Fig. XLVI. on Plate IX, fronting p. 132.*) whose Focus of parallel Rays is at CD, 12 Feet, or 144 Inches distant from itself; let this Lens be fixed in the Window-shutter of a darkened Chamber to receive the Sun's Rays AL, BL, which coming from the extreme Parts of the Sun's Body, and intersecting each other in the Center of the Lens, will determine the Diameter of the Sun's Image at CD, which, when you have nicely measured, you will find to be  $1\frac{3}{100}$  of an Inch. The Half of which is  $Ce = \frac{6}{100}$  of an Inch. Then say,

|                                               |             |        |             |
|-----------------------------------------------|-------------|--------|-------------|
| As the focal Distance                         | CL = 144    | =      | 2.158362    |
| Is to $\frac{1}{2}$ the Diameter of the Image | $Ce = 0.67$ | =      | 9.826074    |
| So is Radius                                  | _____       | 90° 0' | = 10,000000 |

|                          |              |   |          |
|--------------------------|--------------|---|----------|
| To the Line of the Angle | CLe = 0° 16' | = | 7.667712 |
|--------------------------|--------------|---|----------|

Therefore the whole Angle CLD or ALB is 32 Minutes, and this is called his *Apparent Diameter*, because its Diameter appears under such an Angle to the Eye.

3. Now since the Diameter of any *Object* and its Image are proportional to their Distances from the Lens, the Diameter of the Sun will easily be had by the following Analogy.

|                               |               |             |            |
|-------------------------------|---------------|-------------|------------|
| As the Distance of the Image  | CL = 144      | =           | 2.158362   |
| To its Diameter               | _____         | CD = 1.34   | = 0.127105 |
| So is the Distance of the Sun | LA = 82136014 | =           | 7.914533   |
| To his Diameter               | _____         | AB = 764320 | = 5.883276 |

4. Thus his Diameter is found to be *seven Hundred sixty four Thousand three Hundred and twenty English Miles*; which is less, but perhaps truer, than the above assigned. — *Ten Thousand Miles* is a trifling Distance, and not to be regarded in the Measurement of such immense Distances.

† See *Swinden's Book on the Nature and Place of Hell*.

A. The

A. The Quantity of Matter ; pray, in what Proportion is that to the same in other *Planets*?

B. The Quantity of Matter in the *Sun* is to that in *Saturn*, as 100000 to 33 ; to that in *Jupiter*, as 100000 to 92 ; to that in our *Earth*, as 10000000 to 59.

A. In what Proportion is the Weight of Bodies on the *Sun*'s Surface?

B. The Weight of equal Bodies on the Surface of the *Sun* is to their Weight on the Surface of *Saturn*, as 10000 to 529 ; to their Weight on *Jupiter*, as 10000 to 943 ; and to their Weight on the Surface of our *Earth*, as 10000 to 435.

A. What is the comparative Density of the *Sun*?

B. The Density of the *Sun* is to the Density of *Saturn*, as 100 to 67 ; to the Density of *Jupiter*, as 100 to  $94\frac{1}{2}$  ; and to the Density of our *Earth*, as 100 to 400, or as 1 to 4 ; and therefore the Fire of the *Sun* must be prodigious intense, yea, almost solid, as being one Quarter of the Density of our *Earth* \*.

A. Why, then the Light and Heat must be inconceivably great near the *Sun*'s Surface?

B. Yes, great indeed : Sir *Isaac Newton* saith, the *Sun*'s Light and Heat, at the Distance of *Mercury*, is seven Times as great as the greatest with us ; and therefore our Water there would

\* These Proportions of the Matter, Weights of Bodies, and Densities in the *Sun*, *Saturn*, *Jupiter*, and the *Earth*, are taken from Sir *I. Newton*'s *Principia*, Pag. 405. Where the Diameters of these Bodies are determined to be in the Proportion of 10000, 791, 997, and 109,

be for ever Boiling-hot, 'till it was all evaporated, and boiled away \*.

*A.* Is the *Sun's* Body one pure unmixed Substance of Fire ?

*B.* That none can certainly tell ; there hath seemed Reason to doubt it, since the Discovery of the *Maculæ Solares*, or *Solar Spots*.

*A.* Pray, *Sir*, what are they ?

*B.* The Astronomers of late, by proper Glasses, have discovered many black Spots in the apparent Face of the *Sun* ; some suppose they are a heterogeneous Mixture of opaque Matter in the Body of the *Sun*, which therefore in those Parts will always appear dark or black. Some of those Spots seem to be generated in the very Middle of the *Sun's* Disk ; and others seem to be dissolved and vanish there ; sometimes several small ones gather together, and make a large Spot ; and sometimes a large Spot is observed to be divided, and cut into many lesser ones. Some Philosophers have thought they were small *Planets* circulating round the *Sun's* Body very near it ; and others have other Conjectures about them. They were first discovered by *Galileo*, the *Italian* Philosopher, in the Year 1610 †.

*A.* Do.

\* Since the Intensity of *Light* and *Heat* are as the Squares of the Distances reciprocally, and since the Proportion of the Distances of all the Planets from the *Sun* is known, the Proportion of *Light* and *Heat* at each is also easily known, as is expressed in the following *Synopsis*.

† 1. That they who have not had an Opportunity of viewing the Spots in the *Sun*, with a Telescope or otherwise, may have some proper Idea of them, I have carefully delineated such as appeared in the *Sun's* Face on *Aug.* the 25th, 1737, at seven in the Morning, (in *Fig.* XLVII. on *Plate* IX, fronting p. 213.) where



*Of the Solar Spots, the Sun's Motion.* 139

A. Do these Spots appear fixed, or in Motion, on the Sun's Body?

B. They

where the whole circular Area represents the Sun's Face; on which you see the Spots in their proper Magnitudes, and Situations, as they then had.

2. The Number of these Spots is always uncertain and variable; It is said when *Galileo*, *Schinerus*, *Hewelius*, &c. first observed them, that the Sun would frequently wear one or more of these Spots: But now (says Mr. *Molyneux*, who wrote about 40 or 50 Years ago) he seldom wears any of those Patches, as if they were grown out of Fashion, one in five or seven Years hardly appearing. Yet, about the Year 1700, it was not uncommon to observe 10, 16, or 20, and sometimes more Spots on the Sun's Disk. And now as the Sun is scarce ever to be observed without some, so they are generally very numerous, it not being difficult to enumerate 20, 30, or 40 Spots pretty distinctly on the Sun's Face, besides many others which appear dusky and obscure.

3. As to their *Magnitude*, that likewise is very variable, some being scarcely visible, and others are so large even at his Limb, as to take up an 100th Part of his Diameter, and more; and which therefore will be found by Calculation to contain a far greater Number of square Miles than the whole Superficies of our terraqueous Globe.

4. The *Motion* of these Spots is very irregular, so far as I could ever yet observe; I could never find that the same Spots in the same Figure, Number, and Order, ever returned in any regular periodical Manner; and therefore what is here said concerning the Motion of the Sun, is wholly on Credit from others.

5. The *Mutability* of the *Form* or *Shape* of these Spots is very considerable, as is also the Variety thereof; being sometimes long, broad, oval, seldom round, often angular, and pointed in several Parts, and will often vary their Shape while you are observing them.

6. Sometimes those Spots decay, and become shady, nebulous, and of a misty Appearance, and are at last invisible before they go off the Disk. And those Spots and *Nebulæ* or Mists do sometimes suddenly arise, and as suddenly decay and become extinct.

7. Spots which continue long on the Disk of the Sun, are said often to turn to *Feculæ*, or exceeding bright and flaming Parts, which do not continue long on the Sun's Face, before they are extinguished or disappear. But these *Feculæ*, or flaming Spots, are very rare of late, since I have never had the desirable Sight of one of them.

8. The sagacious Mr. *Derham* very rationally supposes, that —The Spots in the Sun are caused by the Eruption of *Vulcano's* therein, the prodigious Quantity of Smoke, and other opacous Matter, making

*B.* They all appear to move from the *Eastern* to the *Western* Limb of the Sun, in about 12 or 13 Days.

*A.* Pray what do you infer from thence?

*B.* Why, was it certainly known (as it is the general Opinion) that those Spots were really in the *Sun's* Body; then, from their apparent Motion, we could be assured of the *Sun's* real Motion about its own Axis, in somewhat above 25 Days and 6 Hours: But if these Spots are only some distinct Bodies actually moving round the *Sun*, then we have no certain Knowledge that the *Sun* hath any real and proper Motion at all.

*A.* How, *Sir*, do you say no Motion at all; pray do we not see him move every Day from *East* to *West*?

*B.* He seemeth, indeed, to us so to move; but that is one of the Fallacies of Sight, and indeed the greatest.

*A.* What! *Sir*, will you pretend to say he doth not move?

*making the dark Spots, which gradually decaying and spending itself, makes the Spots degenerate to Umbræ and Nebulæ; that is, to Shadows and Mists; lastly, the fuliginous Matter being quite dissipated, and spent, the horrid Flames of the Vulcano appear, and make the Feculæ before described.*

9. In observing the Spots, &c. of the Sun, the best Way is to use a Telescope of about 6, 8, or 10 Feet Length, with a smoked Glass placed before the Eye-Glass next the Eye; if in this Case the Telescope be, and a Micrometer fitted thereto, the Spots may with Ease be measured, and their Appearances observed from Day to Day. Also the Sun's Image may be received into a dark Chamber (through a Telescope with an Object-Glass and one Eye-Glass only) on a Piece of white Paper, which may be magnified or diminished as Occasion requires; this is an easy and innocent Way, and that which I generally use.

See much more concerning this curious Subject in the *Phil. Transactions*, N<sup>o</sup> 288, 294, 330; or the same abridged by Mr. Jones, Vol. IV. Page 228 to 245. As also in *Harris's Lexicon*, under the Word *Maculæ*.

B. Yes, Sir, there is no Reason to think he doth move; and there are physical Demonstrations that he doth not move.

A. Pray what are they?

B. One of them is this: *That since the Sun, the Earth, and all the Planets, gravitate mutually towards each other, they must all have one common Center of Gravity, about which they must all move; but Sir Isaac Newton hath shewn and demonstrated, that this Point, or Center of Gravity, is not quite a Diameter of the Sun distant from the Sun's Center; therefore the Earth, and all the Planets, move round a Point not half the Diameter of the Sun, distant from the Sun's Surface; and this is the same Thing to us, as if the Earth, &c. moved about the Sun itself* \*.

A. Well, I cannot confute Sir Isaac, it is true; but I can choose whether I will believe him: Should not I sooner believe the *Word of God*, and my own *Senses*?

B. No: A Demonstration at once commands Assent, notwithstanding the *literal Meaning* of Scripture, and the *Evidence of all our Senses* to the contrary. No one needs be convinced of the Fallacy of Sight, who hath ever been in a Ship under Sail; nor was the Scripture intended for a System of *Physiology* †.

C H A P.

\* *Principia Math. Philos.* Lib. III. Prop. 12. & Corol. The other Physical Demonstration of the Earth's Motion about the Sun, see in *Keill's Astronom. Lectures*, Page 34, 35; or in the *Philolog. Library of Literary Arts and Sciences*, Page 300.

† I am sorry any one should take from hence an Occasion to say that I spake irreverently or ludicrously of the *sacred Scriptures*; I think it would be very dishonourable and ridiculous to urge them in any Sense against a *known and demonstrated Truth* of any



## C H A P. III.

SELENOGRAPHY, *or the PHILOSOPHY of the Moon.*

*A.* **W**HAT is the Etymology of the Word *Selenography*?

*B.* It is compounded of *σελήνη*, the *Moon*, and *γραφή*, a *Description*; wherefore it means a *physiological Description of the Moon*.

*A.* You speak of the *Moon* in the *singular*, as if there was but one; whereas just now you numbered our *Moon* with several others.

*B.* Yes, there are several other *Moons*, as *Jupiter* hath four *Moons*, and *Saturn* hath five *Moons*; but because we know little more of them than their Number, Motions, and Distance from their *primary Planets*, we shall omit them here, and speak of them together with their *Primaries* by and by.

*A.* Well, since the *Moon* is favoured with the Preheminence to be considered alone; pray what do you first observe in her?

any kind. I esteem the Bible not only a just History of Facts, but a divine Revelation, and the best System of natural Religion in being; but I am so far from thinking that we are to be directed in our Sentiments of natural Science, especially *Philosophy* and *Astronomy*, by the Scriptures, that I am apt to believe those Sciences, as they are now and truly understood, were entirely unknown to the Writers of those Books.

But if any one gives himself the Trouble, he may see the Arguments for the Sun's Motion fairly stated, and fully confuted, in *Varenius's Geog. General. Par. I. Lib. I. Cap. 5. Atlas Geog. Introduction, § 12. Joan. Clerici Physica, Lib. 1. Cap. 2. & 3. Galilæi System. Cosmic. Pag. 354, 356, 457, 492, 644. Epistola Paul. Anton. Foscarini, wholly on the Subject.*

*B.* It

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B. It is found that the Body of the *Moon* is a large, dark, opaque, spherical Body, alike to our *Earth* in Matter and Form.

A. What Proportion doth the *Moon* bear to the *Earth* in its *Magnitude* and *Density* of Matter?

B. The Bulk of the *Moon* is to that of the *Earth*, as 586333000 to 258445900000, or as 5 to 258; that is, the *Earth* is about 50 Times (at least) bigger than the *Moon*; the Density of the *Moon* is to the Density of the *Earth*, as 4891 to 4000, or as 11 to 9; the Quantity of Matter in the *Moon* is to that of the *Earth*, as 1 to 40, or as 1000 to 39788, more nearly; and the Weight of Bodies on the *Moon*'s Surface, is to their Weight on the *Earth*'s Surface, as 34 to 100 \*.

A. Can you tell the particular Dimensions of the *Moon*'s Body in *English* Measure?

B. Yes; the Diameter of the *Moon* is 2175 *English* Miles, her Circumference therefore must be 6829 Miles; whence the Superficies of the *Moon* will contain 1415440 square Miles, and her solid Content will be 5386333000 cubic Miles, as before.

A. On what do these Measures depend?

B. On the Distance of the *Moon* from the *Earth*; which some Astronomers make 59, some 60, some 61, Semi-diameters of the *Earth*, that is, about 238920 *English* Miles; whence the Diameter of the *Moon*'s Orb will be 477840 Miles, and Circumference thereof 1500418 Miles; which therefore is the Journey the *Moon* performs every Revolution †.

A. Then,

\* See *Newton. Princip. Philos.* Pag. 468, 469.

† The Distance of the *Moon* from the *Earth* is thus found.  
(See

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*A.* Then you do allow the *Moon* to move about the *Earth* every Day from *East* to *West*, though you deny this to the *Sun*?

(See Fig. XLVIII. on Plate IX, fronting p. 132.) Let ABC be the Earth, V the Moon in the Zenith, and D the Moon in the Horizon: BD is the *sensible Horizon*, and CH the *true or rational Horizon*. Suppose the Moon in that Part of her Orbit nearest the Earth; an Observer at B would see the Moon in the Line BD, but to an Eye placed in the Center of the Earth C, she would appear in the Line CD; the former is her *apparent Place* known by Observation with exact Instruments; the latter, her *true Place*, and is known from the *Theory*, or Table: The Difference of these two Places is found to be  $1^{\circ} 2' 10''$ , and is the Measure of the Angle BDC, which is called the Moon's *Horizontal Parallax*; the Angle at B is a Right one, and BC is the Semi-diameter of the Earth. Wherefore, in the Triangle BDC we can easily find the Side BD, the Distance of the Moon from the Observer B, by the following Analogy:

As the Sine of the Angle D  $= 1^{\circ} 2' 10'' = 8.257419$

To the Side ——— BC  $= 1 = 0.000000$

So is the Sine of the Angle BCD  $= 88^{\circ} 57' 50'' = 9.999929$

To the Side ——— DB  $= 55.27 = 1.742510$

That is, the Moon (when nearest the Earth) is  $55 \frac{27}{100}$  Semi-diameters of the Earth distant from the Point B. But a Semi-diameter of the Earth is 3982 Miles, which multiplied by  $55 \frac{27}{100}$ , gives  $220085 \frac{5}{100}$  Miles, her nearest Distance from the Observer at B. In the same Manner you find the Side CD  $= 220344 \frac{78}{100}$  Miles, her nearest Distance from the Center of the Earth. But her *mean* and *greatest Distance* is variously determined, as above hinted.

Again, to find the Diameter of the Moon in Miles, let P be the Moon, and O her Center, join CO and PC; then is the Angle OCP equal to the apparent Semi-diameter of the Moon at the Center of the Earth, which, for the abovementioned *Horizontal Parallax*, is  $16' 52''$  (see Note \* in Page 136) and CO is equal to CD  $= 220344 \frac{78}{100}$ , and the Angle at O is a *Right* one, whence the Side PO is thus found:

As the Sine of the Angle CPO  $= 89^{\circ} 43' 8'' = 9.999995$

To the Side ——— CO  $= 220344 \frac{78}{100} = 5.342611$

So is the Sine of the Angle OCP  $= 16' 52'' = 7.690663$

To the Side ——— OP  $= 1079 \frac{6}{100} = 3.033269$

Which is the Number of Miles in the Semi-diameter of the Moon, the Double whereof, *viz.*  $2159 \frac{2}{5}$  is the Number of Miles in the Moon's true Diameter. This indeed is 16 Miles less than that assigned in the Text, but the Difference is too small to be regarded.

*B.* The



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B. The *Moon* doth, indeed, move about the *Earth*, and that in about 27 Days, 7 Hours, and 43 Minutes, at a mean Rate: But this Motion is not from *East* and *West*, but, on the contrary, from *West* to *East*, every Day about 13 Degrees and 10 Minutes.

A. How comes it then to appear to do thus?

B. By reason of the daily Motion of the *Earth* about its own Axis from *West* to *East* once in 24 Hours; which maketh the *Sun*, *Moon*, and all the *heavenly Bodies*, appear to move the contrary Way from *East* to *West* in the same Time.

A. Pray why do we see the *Moon* rise and set above an Hour later every Day than another?

B. I shall make this easy to conceive. Thus, suppose T be the Globe of the *Earth*, WSEN the Orb of the *Moon*; let AD represent the *Horizon*, in which let the *Moon* D be, on any Day at her rising and setting, in E and W: Now, because the *Moon* moves every Day about  $13^{\circ} 10'$  from *West* to *East*, let that Distance be represented in the *Moon's* Orb by WF and EH; therefore at the same Time, on the following Day, the *Moon* will be under the *Horizon* at H at her rising, and above the *Horizon* at F, at her setting the Day before; where the Surface of the *Earth* must turn from A to B, and from D to C, before the *Moon* will be again in the *Horizon* at rising or setting; which Motion from A to B, or from D to C, takes up about an Hour's Time, more or less, every Day. See Fig. XXI. on Plate XIII, fronting p. 155\*.

A. Sir,

\* In an oblique Sphere, all great Circles intersecting the *Equinoctial* will, in the Revolution of the Sphere, intersect the *Horizon* with

*A.* Sir, I thank you ; I perfectly understand you, and the Meaning of this *Phænomenon* : Pray hath the *Moon* any other Motion ?

*B.* Yes : She revolves about her own Axis just in the same Time she performs one Revolution about the *Earth*, viz. in 27 Days 7 Hours 43 Minutes \*.

*A.* How are you sure of that ?

*B.* Because at the same Times we always see the same Face or Side of the *Moon* ; but this could not happen, unless a proper Motion about her Axis turned every Day just so much of the *Moon's* Body to the *Earth*, as her periodical Motions turn from it.

with different Angles at every different Part thereof. Thus with respect to the Ecliptic, when the Beginning of *Libra* is orient, or rising in the East, it then makes the greatest Angle with the Horizon ; when Capricorn is orient, the Angle is mean, and when Aries is orient, the Angle is least of all ; and therefore when the Moon is full in the Beginning of *Libra*, one Day's Motion depresses her farthest below the Horizon, and least when in the Beginning of *Aries* ; consequently, the Difference of her rising each Day at the *vernal Equinox* will be greatest, and least of all in the *autumnal Equinox*.

Now since the Moon's Orb intersects the Ecliptic in an Angle of about five Degrees, when these Points of Intersection shall happen to be in the *Equinoxes*, a full Moon in the Beginning of *Libra* will rise later the next Day after by one Hour and about 20 Minutes ; and in the Beginning of *Aries*, by the Difference only of about 20 Minutes. And if the Moon be in *Perigeum* at such Times, the Intervals of her rising will still be greater in the former Case, and lesser in the latter. Thus the *Autumnal full Moon* rises near an Hour sooner, the next Day, than the *Vernal* one ; whence, by Way of Distinction, it is vulgarly called the *Harvest Moon*.

\* The Revolution of the Moon through the *Zodiac* is called a *Lunation*, and 12 of these Lunations or Revolutions is a *Lunar Year* ; and which takes up the Space of 354 Days 8 Hours 48' 38". The Difference between this and the *solar Year*, which contains 365 D. 5 H. 48' 57", is almost 11 Days, which Chronologers call the *Epacr*. See my *Philolog. Library*, Page 338, 350, &c.

And because the Moon's Motion about her Axis is performed in the same Time as about the *Earth*, the *Lunarians* have their *Nyothemerion* or *Natural Day* equal to their Months.

*A.* This

A. This must be a wonderful Harmony and Correspondence of Motions, indeed! But what is the Form of the *Moon's* Orbit?

B. The *Moon's* Orbit is elliptical, but is perpetually changing, and never continueth the same Species, or of the same Figure.

A. How so?

B. The Causes of Inequalities of the Motions of the *Moon*, and the Form of her Orbit, are the different Attractions of the *Sun* and *Earth*, the Eccentricity of her Orb, and the Obliquity of the Axis of her daily Motion \*.

A. I think you agree, the *Moon* receives all the Light she shines with from the *Sun*?

B. Yes, she does so; and by Reflection conveys it to us in the *Sun's* Absence †.

A. Pray, Sir, give me Leave to ask what is the Reason why some Parts of the *Moon's* Face look dark, and others light?

B. The bright Parts of the *Moon's* Body are the more eminent Parts of Land, which reflect the Light of the *Sun*, as Hills, Mountains, Promontories, Islands, &c. and the dark Parts of the *Moon* are thought to be Seas, Lakes, Rivers, Fens, &c. by some; and by others, they are said to be shaded Vallies, Caverns, Pits, &c. But in Truth they represent both Water and shaded Places; for neither of these reflecting Light, must appear dark, and not bright.

\* Concerning the Irregularities of the Moon's Motion, and her compleat Theory, see *Newton*, Princip. Lib. III. *Gregory's*, *Whiston's*, and *Keill's* Astronomy; also Mr. *Leadbetter's* Books of Astronomy.

† The Sun's Light by Reflection from the Moon is so very weak and effæte, that it cannot be made to produce any sensible Heat by the best of *Burning-Glasses* yet made.



*A.* Then you suppose the *Moon* to be inhabited, I find? I have heard there be some of that Opinion.

*B.* Yes, undoubtedly; to what End else can serve the Distribution of Land and Water, Mountains and Vallies, Caverns, Pits, &c.? Besides an *Atmosphere* of Air (and thereby Winds, Clouds, Rain, and other Meteors of Consequence) has been lately discovered about it: No doubt but they serve the Purposes there, as here, to nourish and sustain Men, Beasts, and Vegetables \*.

*A.* Indeed, if it be so, your Reasoning and Inferences are very just: I wish I could have the Happiness of viewing the Face of the *Moon* through a good *Telescope*, for my own Satisfaction.

*B.* It is a very great Curiosity indeed; I can tell, because I have thus viewed it many Times; I should be glad if the Weather would permit me now to gratify you in this Particular; however, to make amends for that, I can shew you the Face of the *Moon* curiously engraven, and just as it appears through such a Glass, with the Names which several Sele-

\* That the Moon is inhabited, few have doubted; but it is a great Question with some whether there be an *Atmosphere* about her, and others flatly deny it. See *Hugens's Cosmoth.* Book II. and *Keill's Astron.* Lect. X.

The Moon through a good Telescope not only appears perfectly globular when at full, but at other Times to have all the Varieties of *Mountains, Vales, and Seas*, as we may suppose a Lunarian can behold in our Earth.

They who would see the Manner of measuring a *Lunar Mountain*, may consult Mr. *Derham's Astro-Theol.* Book V. Chap. 2. in the Notes, and the Authors there referred to. As also my *Young Trig. Guide*, Vol. I. Part II. Chap. 3. Sect. 20. and *Keill's Astr.* Lect. X, Page 107.

nogra-





To front Page 149.

Plate XI.

Fig: XX.



Em: Devenant Scult



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nographists have given to the several light and dark Parts thereof. See *Fig. XX.* on *Plate XI*, fronting *p.* 149.

#### C H A P. IV.

*Of PLANETOGRAPHY, or the PHILOSOPHY of the PLANETS.*

A. **P**RAY what is the original Meaning of the Word *Planet*?

B. It is a *Greek* Word, and derived from the Verb *πλανάομαι*, to *wander* or *stray*; whence the *English* of this Word is, a *wandering Star*.

A. I think I remember, you told me there were two Sorts of those *Planets*, or *wandering Stars*; the first you called *primary Planets*, the other *Secondaries*, or *Moons*, or *Satellites*?

B. It is true, I did: And the *primary Planets*, viz. *Mercury*, *Venus*, the *Earth*, *Mars*, *Jupiter*, and *Saturn*, are principally here intended, as the Subject of our present Discourse; and the *Secondaries* we will only consider amongst the Accidents of the *Primaries*.

A. Well, since a *Planet* hath its Name from its Motion, we will first begin with the Motions of the *Planets* if you please: And, pray, in what Order, Form, or Manner, do the *Planets* move?

B. I have already said, that the *Sun* is the Center of our System; about which the *Planets* all revolve in different Distances; 1. *Mercury*, 2. *Venus*, 3. *Earth*, 4. *Mars*, 5. *Jupiter*, and 6. *Saturn*, as you see them in the Solar System; the Form of their Motion is elliptical more or less, and not perfectly circular; and they all move

round the *Sun*, in such Manner, as to describe equal Areas of Space in equal Times.

*A.* Pray, Sir, if you can, illustrate this Matter by a Scheme.

*B.* Sir, that may be done very easily. Thus, let *S* be the *Sun*, *ABPCD* the elliptical Orb of a *Planet P*; then the Part of the Orb *P* is called the *Perihelium*, being the nearest Distance from the *Sun*; and the Part *A* is called the *Aphelium*, as being the farthest Distance from the *Sun*; and *SE* is called the *Eccentricity* of the *Planet*; and as this *Eccentricity* is less or greater, so the Orb of the *Planet* is less or more elliptical. See *Fig. XXII.* on *Plate XIII.* front-p. 155.

*A.* But you have not yet shewed what is meant by a *Planet's* describing equal Areas in equal Times.

*B.* This is no more than to say, if the Times, in which the *Planet* moves in his Orb from *P* to *C*, and from *C* to *D*, and from *D* to *A*, be equal to each other, then the Areas or Spaces *PSC*, *CSD*, and *DSA* (described in those equal Times, by Lines drawn from the *Planet* to the *Sun*) will also be equal among themselves, and the contrary \*.

*A.* But, pray, do you assign such very unequal Portions of the Orbit to be passed over in equal Times? Do not the *Planets* move equal Distances in their Orbs in equal Times?

*B.* No, very far from it; for the Velocity of a *Planet's* Motion is different in every Part of its Orb, being sometimes greater, and sometimes less.

\* By the contrary is meant only, that if the Areas described be equal among themselves, the Times in which they were described will also be equal. See *Newton*, Princip. Lib. III. Prop. XIII.

*A.* How

A. How happens that ?

B By Gravity, or the *Sun's* Attraction : For, when the *Planet* is in P, the *Sun* attracteth it most strongly ; and therefore the Motion there, and thereabouts, is greater than any where else. Again, when the *Planet* is in its *Aphelium* at A, at its greatest Distance from the *Sun*, it is then least affected by the Power of Gravity, and consequently the Motion there, and thereby, is the least or slowest of any Place in the Orb. But, when the Motion is so unequal, the Arches PC, CD, DA, must needs be so too, though described in equal Times.

A. Sir, I conceive it must be so now ; I did not think of the *Sun's* Attraction : Since therefore those Areas are always proportional to the Times, pray, what Proportion of Gravity or Attraction will produce this ?

B. The Power of Gravity is always reciprocally as the Squares of the Distances of the *Planet* from the *Sun* : Thus, suppose the Distances SP, SC, SD, SA, were as the Numbers 5, 6, 9, 10, then the Power of Attraction in those Distances would be reciprocally as their Squares, viz. 100, 81, 36, 25 ; so that it would be four Times greater in the *Perihelium* P, than in the *Aphelium* A ; and this is the constant Law of all the *Planets* both primary and secondary.

A. Pray what other Affections are observable of the planetary Motions ?

B. The *Planets*, as I told you, all move about the *Sun* in reality from *West* to *East*, and yet they sometimes appear to move the contrary Way from *East* to *West*, and sometimes not to



move at all for some Time ; and thus they are said to be *direct*, *stationary*, or *retrograde*.

*A.* I should be glad if you could explain this to my Apprehension by a clear and easy Scheme.

*B.* That I will endeavour to do : Therefore let *S* be the *Sun*, *ACE* the Orb of the *Earth*, and *FGI* a Part of the Orb of any one of the superior *Planets*, suppose *Jupiter* ; also let *QR* represent the Arch of the starry Heavens, wherein we see and determine the Places and Motions of all the *Planets* (see *Fig. XXIII.* on *Plate XIII.* fronting *p. 155.*) Now, suppose the angular Motion of the *Earth* be so much greater than that of *Jupiter*, that while the *Earth* describes the Arch *ECA*, *Jupiter* shall only describe the Arch *HGF* ; then it is easy to conceive, that, when the *Earth* is in *E*, the *Planet* at *H* will be seen amongst the fixed Stars at *M*, and so he will also, when the *Earth* is arrived at *D* ; therefore all the Time the *Earth* is passing from *E* to *D*, the *Planet* will seem to stand still about *M*, and is said to be Stationary : Again, when the *Earth* is arrived to *C*, the *Planet* will really be moved forwards to *G*, but will be seen from the *Earth* at *C*, amongst the Stars at *N* ; wherefore, while the *Earth* passeth *Eastward* from *D* to *C*, the *Planet* will appear to move *Westward* from *M* to *N* in the Heavens, which is backward ; also, while the *Earth* moves from *C* to *B*, the *Planet* will still seem to move backwards from *N* to *O*, where it will again be Stationary till the *Earth* comes to *A*. Do you understand me ?

*A.* I believe I do : You mean, that while the *Earth* passeth from *E* to *D*, and from *B* to *A*, the

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Fig: XLIX  
Page 153.

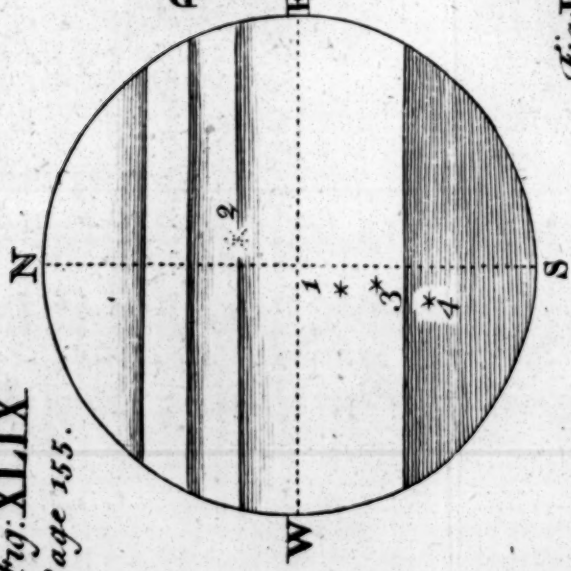


Fig: L.  
Page 155.

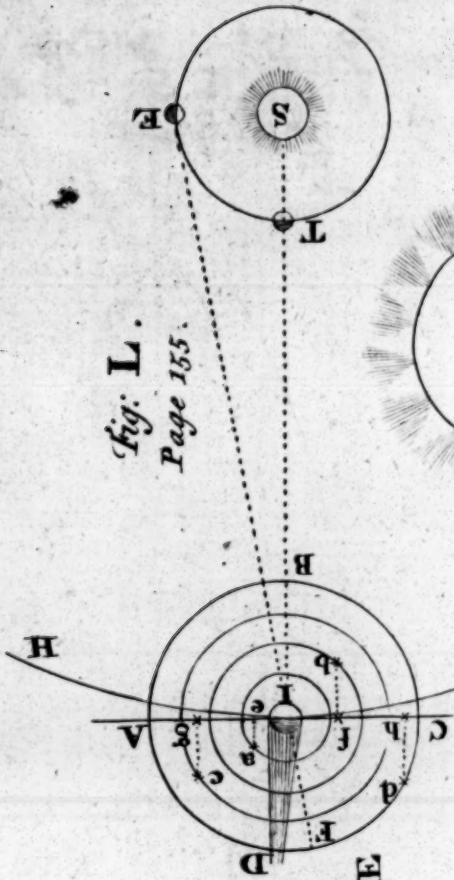


Fig: LII.  
Page 155.

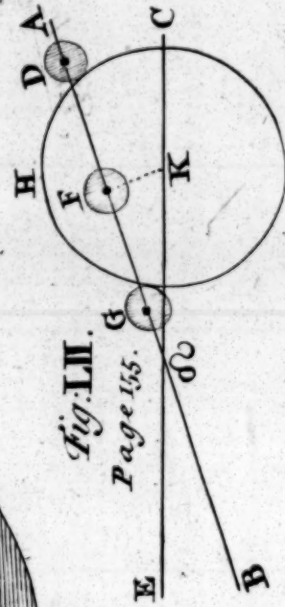


Fig: LI.  
Page 155.

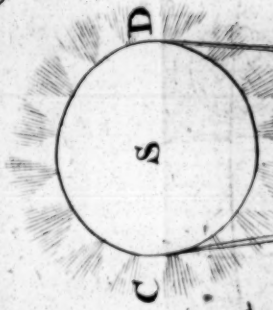


Fig: LIV.  
Page 177.

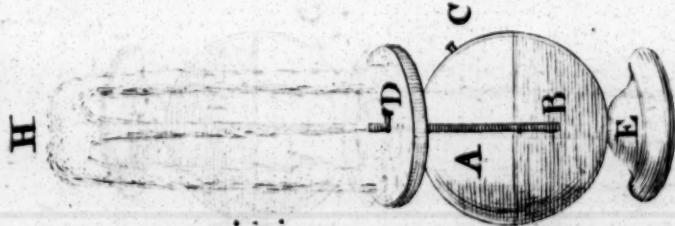


Fig: LIII.  
Page 157.

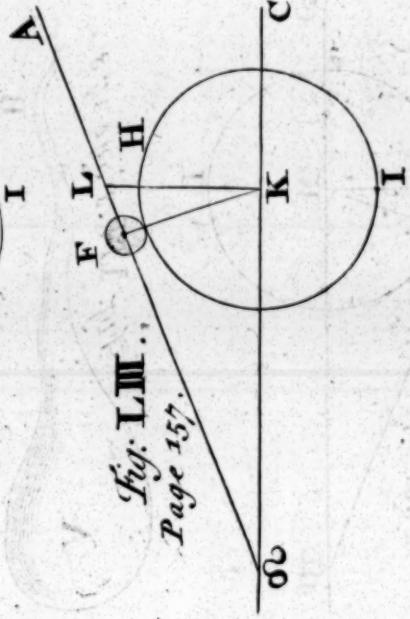
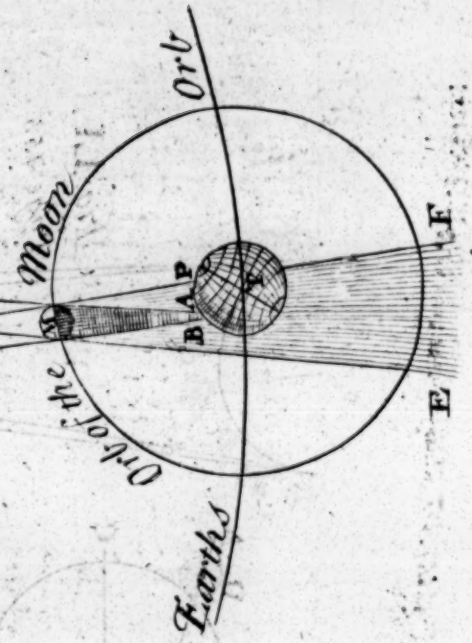


Fig: LV. Page 178.





the Planet *Jupiter* will appear not to move in the Points M and O; and then he is said to be Stationary: Also, while the *Earth* is passing from D, by C to B, and though *Jupiter* really moves in his Orb from H to F *Eastward*, yet he will seem to us to move from M to O *Westward*, or *Backwards*; and during that Time is said to be Retrograde: I think this is the Matter as you intended I should understand it; is it not?

B. Yes, I am glad to see you understand this intricate Phænomenon so well; and in a like Way you may understand the same of the inferior *Planets*.

A. Pray what particular Affections hath each *Planet*?

B. *Eclipses* are peculiar to the *Earth*, *Jupiter*, and *Saturn*, because those *Planets* in particular have *Moons* or *Satellites* moving round them, which occasion those *Eclipses*; also one Thing is particular or peculiar to *Saturn* alone, and that is a surprising Kind of a Ring, encircling the Body of this *Planet* at a great Distance. Lastly, *Jupiter* hath the Appearance of Belts girding his Body; and *Jupiter*, *Mars*, and *Venus*, are found to have dark Spots on their Disks.

A. Well, that we may have some regular Account of those wonderful Particulars, let me know first concerning the Nature, Number, and Distances of the *Moons* or *Satellites* pertaining to the primary *Planets*.

B. The *Earth* hath one *Moon*, of which already: *Jupiter* hath four *Moons*, and *Saturn* five *Moons*: The Times in which they severally revolve about their Primaries, and their Distance in Semi-

# 154 The PHILOSOPHICAL GRAMMAR.

Semi-diameters of the Bodies of *Jupiter* and *Saturn*, are as here follow :

## In *Jupiter*.

|                    | D. | H. | M. |                                                       |    |                               |
|--------------------|----|----|----|-------------------------------------------------------|----|-------------------------------|
| 1 <i>Satellite</i> | 1  | 18 | 27 | Distance<br>from <i>Jupi</i> -<br><i>ter's</i> Center | 5  | $\frac{6}{10}$                |
| 2 ———              | 3  | 13 | 13 |                                                       | 9  |                               |
| 3 ———              | 7  | 3  | 42 |                                                       | 14 | $\frac{3}{10}$                |
| 4 ———              | 16 | 16 | 32 |                                                       | 25 | $\frac{29}{100}$              |
|                    |    |    |    |                                                       |    | Semid. of<br><i>Jupiter</i> . |

## In *Saturn*.

|                    | D. | H. | M. |                                            |    |                                       |
|--------------------|----|----|----|--------------------------------------------|----|---------------------------------------|
| 1 <i>Satellite</i> | 1  | 21 | 18 | Distance<br>from <i>Saturn's</i><br>Center | 1  | $\frac{9}{10}$                        |
| 2 ———              | 2  | 17 | 41 |                                            | 2  | $\frac{2}{5}$                         |
| 3 ———              | 4  | 12 | 25 |                                            | 3  | $\frac{2}{5}$                         |
| 4 ———              | 15 | 22 | 41 |                                            | 8  |                                       |
| 5 ———              | 70 | 22 | 4  |                                            | 23 | $\frac{3}{10}$                        |
|                    |    |    |    |                                            |    | Semid. of<br><i>Saturn's</i><br>Ring. |

These *Moons*, and their *Affections*, were all discovered by Means of the *Telescope*; and, before its Use, were unknown to the *Antients* \*.

## A. They

\* 1. In the Beginning of the Year 1665, the famous *Chris. Hugen* discovered the biggest of *Saturn's* *Satellites* with a *Telescope* of 12 Feet, and is the fourth from *Saturn*. The other four *Satellites* of *Saturn* were all the Discovery of Mr. *Cassini*, the 3d and 5th in the Year 1671, 1672, and 1673; but the 1st and 2d were not discovered till the Year 1684, by extraordinary Glasses of 80, 100, 150, and 200 Feet in Length.

2. All *Jupiter's* *Satellites* were discovered by *Galileo*, on Jan. 7, 1610; and from that Time to this no more than four could ever be seen. These *Moons* are easily seen with a 2, 3, or 4 Feet Glas, especially with short focus Eye-Glasses; but to make exact Observations of their Motions, a Glas of 10 or 12 Feet is necessary; but a good Reflecting *Telescope* of 4 or 6 Feet is sufficient for viewing or observing the *Satellites* either of *Jupiter* or *Saturn*.

3. M. *Molyneux*, in the Year 1681, Nov. 2, at 10 at Night, observed a total Disappearance of all *Jupiter's* *Satellite*, at once; *Ju*-  
*piter*





To front Page 155.

Plate XIII.

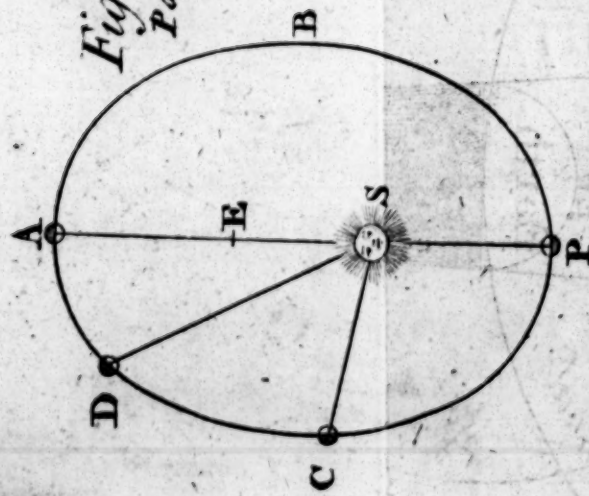


Fig. XXII.  
Page 150.

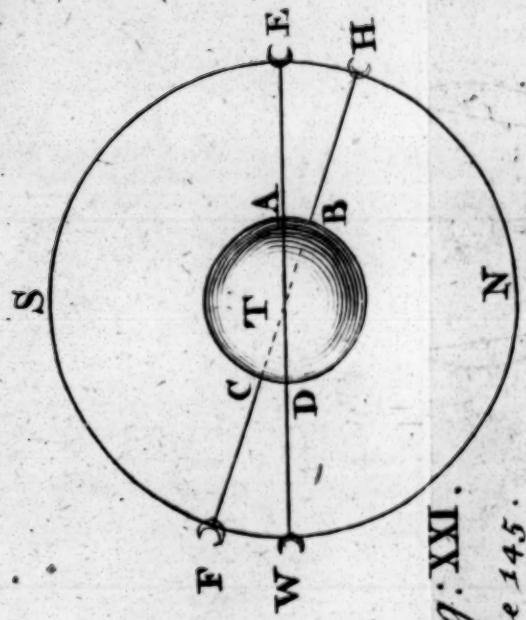


Fig. XXI.  
Page 145.

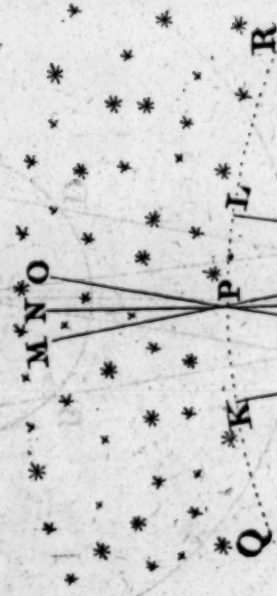
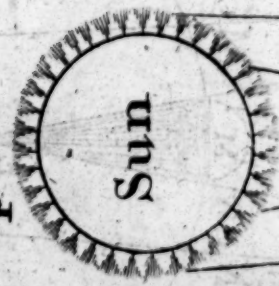
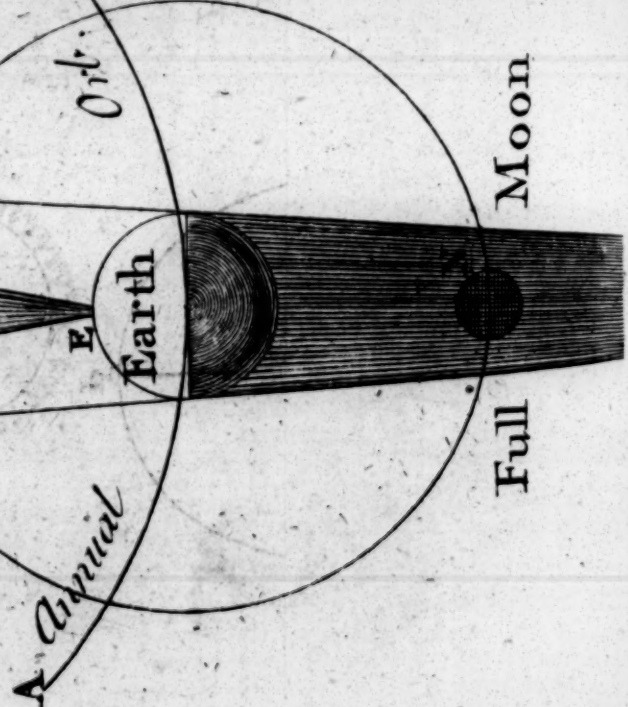


Fig. XXIV.  
Page 155.



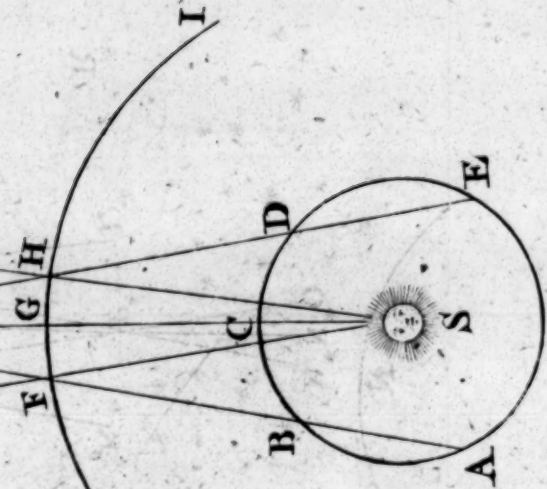
New Moon

Moon



Full Moon

Fig. XXIII.  
Page 152.



*Of the Satellites of Jupiter, and Saturn.* 155

A. They are certainly noble Discoveries; but you say they are the Cause of *Eclipses* to their Primaries; how, I pray you?

B. This, both in the primary, and also in the secondary *Planets*, will be best understood by a Scheme, shewing the *Eclipses* of the *Earth* and *Moon*: For, in *Fig. XXIV.* on *Plate XIII.* fronting *p. 155*, you observe the *Earth* E, in her annual Orb AB, moving about the *Sun*; at the same Time, you observe the *Moon*

*piter* then appearing solitary, as it were deserted by his Guards; and a bold *Lucian* might have pulled him from his Throne without Resistance, says the jocular Author. But they were the 1st, 3d, and 4th on his Face, and the 2d behind his Body, in the Manner as represented in *Fig. XLIX.* on *Plate XII.* fronting *p. 153.* See *Molyn. Diopt.* Page 271, &c.

4. For the *Satellites* of *Jupiter* or *Saturn* may be rendered invisible to us four different Ways, (see *Fig. L.* on *Plate XII.* fronting *p. 153.*) Let S be the Sun, E the Earth, I *Jupiter* in his Orbit GH, and *a, b, c, d*, his four *Satellites* about him. Then, (1.) A Satellite may be eclipsed by *Jupiter's* Shadow ID. (2.) It may be hid behind the Body of *Jupiter*, in the Line IF. (3.) It may pass over the Face of *Jupiter*, whose greater Light will render that of the Satellite insensible. (4.) Lastly, One Satellite may pass before and intercept the Light of another; though this is a Case that very rarely happens.

5. Notwithstanding the *Satellites* have all a circular Motion about their *Primary*, yet when they are viewed, they appear to be, and to move in a straight Line situated East and West. The Reason whereof is, that since the Planes of the Orbits of the *Satellites* do nearly pass through the Eye of the Spectator, either half of any of their circular Orbits, as ABC or ADC, will be projected into its Diameter AC, and consequently its Satellite with it; and thus the *Satellites*, if situated in the Orbit in *a, b, c, d*, will appear to a Spectator on the Earth at T, in the Right Line AC in the Points *e, f, g, h*.

6. Also, while the Satellite is in the nearest Semi-circle CBA, he appears to move from East to West in the Line CA; but while he passes the remote Semi-circle ADC, he will then appear to return from the West to East along the same Line AC; so that in one Revolution he appears to move twice through the Right Line AC.

7. From hence also it appears, that the most distant Satellite may appear nearer the Body of *Jupiter* than the nearest; and the contrary; which is so easy to conceive, that I need not perplex the Scheme for an Example,

moving



moving about the *Earth* in her Orb: Now when the *Moon* is in Conjunction with the *Sun*, *i. e.* when she is just between the *Earth* and *Sun*, and is what we call the *New Moon*, as at M; then it is evident her Shadow will fall on the *Earth* at E, and consequently will hide some Part of the *Sun's* Body from those who dwell on that Spot; and this is what they call an *Eclipse* of the *Sun*, but is properly an *Eclipse* of the *Earth*; for you see it is the *Earth* that is really darkened, and not the *Sun*: Also it is evident, when the *Moon* is in the opposite Part of her Orb at N, in direct Opposition to the *Sun*, that then the *Earth* being exactly between the *Sun* and the *Moon*, will cast her Shadow on the *Moon*; and the *Moon* being thus overwhelmed in the Shadow of the *Earth*, will appear dark or dusky, and is properly said to be then eclipsed.

A. This, indeed, is so plain and evident, I believe none can look on it, and not apprehend the Manner and Cause of *Eclipses*. Pray, can you tell the Quantity of *Eclipses*?

B. Yes; the dark Shadow of the *Moon* covers a Part of the *Earth's* Surface about 180 Miles in Diameter, and moveth at the Rate of 2104 Miles an Hour: But the *partial* or *penumbral* Shadow extends to the Width of 4900 Miles: And as to Lunar *Eclipses*, the Diameter of the *Earth's* Shadow at the *Moon*, is near three Times greater than the Diameter of the *Moon*; and therefore the *Moon*\*, in central *Eclipses* of her

\* The Nature of a *Solar Eclipse* will be further evident from Fig. LI. on Plate XII, fronting Page 153, where S is the *Sun*, T the *Earth*, and M the *Moon*. From the Extremities of the *Sun*



her Disk, is totally darkened, or eclipsed, for some Time.

A. So,

Sun draw CF and CB on one Side, and DE and DA on the other, touching and including the Moon's Diameter. Then it is manifest, there will be two Kinds of Shadows produced from the Moon; one determined by the Rays CB and DA, and is properly called the *dark Shadow*, because an Eye placed with that cannot possibly see any Part of the Sun's Disk. The other is determined by the Rays CF and DE, and is called the *Penumbra*, or *partial Shadow*, because to an Eye placed therein, the Sun will be in *part visible*, and *partly obscured*; and as the dark Shadow is a *Cone*, whose Base is the Moon, so the *penumbral Shadow* is also a *Cone* in a contrary Situation, its *Vertex* being above the Moon at V, and its Base at an infinite Distance; though the Part of this Cone above the Moon be only *imaginary*, and is equal to the Cone of the dark Shadow below the Moon.

From a View of the Figure, then, it must be plain, that the Inhabitants of the Earth between P and A will be within the *partial Shadow*, and will perceive only a Part of the Sun eclipsed, which *partial Eclipse* will be so much the greater, by how much the Spectator is near to A. At A the Sun begins to be wholly obscured, and all within the Section of the dark Shadow AB will perceive a total Eclipse of the Sun, which ends at B, where it again becomes *partial*. And this is the *dark and penumbral Shadow*, whose Dimensions were above given. In some *New Moons*, the Latitude of the Moon from the *Ecliptic* is such, that only the *penumbral Shadow* can fall on the Surface of the Earth, in which Case there will be only a *partial Eclipse*; and sometimes the Latitude will be so great, as to give the Earth Room to pass by the *Penumbra* without touching it, and then there will be no Eclipse at all.

The manner of representing a *Solar Eclipse* in this Way, is purely *physical*, or according to *Nature*; but the more *Astronomical* Way, is that according to *Fig. LII. on Plate XII, fronting Page 153*, where the Moon's visible Way AB is represented intersecting the *Ecliptic* or Path of the Earth (at the Time of the *Eclipse*) in the Point s, called the *Node*. The Circle HCI is the Surface of the Earth, and D, F, and G the Section of the *penumbral* and *dark Shadow* of the Moon, as seen from the Moon on the Earth in the Time of the Eclipse. At D the Shadows are just entering on the Disk of the Earth, and the Eclipse begins; the Middle whereof is at F, and at G, the Shadow is got clear off the Disk, and the Eclipse ends.

In *Fig. LIII. on Plate XII, fronting Page 153*, the Latitude of the Moon KL is such, that the Shadow only touches the Disk, but does not enter or obscure any Part thereof. In this Case,

*A.* So, I suppose, *Eclipses* happen to *Saturn* and *Jupiter*, on Account of their *Moons*; and likewise to the *Moons* themselves, as well as to our *Moon*?

*B.* Yes; but the *Eclipses* of those *Planets* are much more frequent than of our *Earth*, the Number of *Moons*, and their quick Circulations, necessarily making them so; also the *Eclipses* of those *Moons* or *Satellites* are very frequent, one or the other being continually passing thro' the Shadow of their Primary.

*A.* Well, leaving the *Moon* and their *Eclipses*, pray let me hear a Word or two about the wonderful Ring of *Saturn*, that you mentioned just now.

*B.* This most surprising *Phænomenon* of all the visible World, was first discovered about 100 Years since: It is of a prodigious Size, great Breadth, and vast Compass; it is said the Distance of the inner Border of the Ring, from the Body of *Saturn*, is equal to the Breadth of the Ring itself, each being computed to be at least 21000 Miles; though others make the Interval between the Ring and *Saturn's* Body to

Case, the Distance  $K\delta$  is the Limit of the Eclipse, because the Earth within that Limit will receive the Shadow in Part or Whole, and beyond it it will not. Now the Angle  $A\delta C$  is variable, and when least, the Ecliptic Limit  $\delta K$  is greatest; and when that Angle is greatest, the said Limit is least. The Limit, when least, is  $14^{\circ} 6' 36''$ , and when greatest,  $16^{\circ} 18' 3''$ .

After a like Manner you consider an *Eclipse* of the *Moon*, whose *Ecliptical Limits* or Boundaries are, the greatest  $12^{\circ} 2' 24''$ , and the least  $9^{\circ} 31' 24''$ .

See more concerning these Affairs in Mr. *Whiston's* and *Keill's* *Astron. Lectures*, and my *Young Trigon. Guide*, Vol. I. Part II. Chap. 3.

*Of Saturn's Ring and Jupiter's Belts.* 159

be 210265, and the Breadth of the Ring to be 29200 Miles; its Thickness is unknown, as being too little for Observation; it hath a Variety of Aspects, sometimes appearing a large *Ellipsis*, then a smaller; sometimes only as a straight Line, and sometimes not visible at all: These are the most remarkable Particulars of this Prodigy of Nature known by us; as to the Matter of which it doth consist, that is not known by any. I have given you a Representation thereof in *Fig. XXV. on Plate XV, fronting p. 187\**.

*A.* This is astonishing, and full of Wonder and Amazement indeed! But did not you say somewhat of a like Nature pertained also to *Jupiter*; pray what are those *Belts* of his you mentioned but now?

*B.* Those *Belt-like* Appearances of *Jupiter* are supposed to adhere to, or be in the Surface of his Body, and not at a Distance from it, as the Ring of *Saturn* is from him; they are four or five in Number, and appear as represented on *Jupiter's* Body in *Fig. XXV. on Plate XV, fronting p. 187.*

*A.* And, pray, what are those Belts supposed to be?

*B.* Some have imagined they are long Canals of some fluid Matter, or Water; and, because they have also observed several dark Spots on the Disk of *Jupiter*, they conclude his Surface

\* The celebrated *Galileo* was the first who discovered any thing extraordinary in the Phasis of *Saturn*, *An. Dom. 1610, October.* But *Mr. Hugen* first discovered it to be a *Ring* encompassing his Body at a Distance, and published it to the World, *An. 1659*, in his Book called the *Saturnian System.* See more concerning this *Phænomenon*, in *Dr. Gregory's*, *Dr. Keill's*, and other Books of *Astronomy*; as also *Mr. Derham's Astro-Theology.*



is divided into Land and Water, as that of our Globe is, and is therefore inhabited; as they also suppose all other *Planets* are \*.

*A.* Then they imagine the *Planets* to be so many Earths, or peopled Worlds? But do not the different Distances of the *Planets* render that impossible, by occasioning too great Light and Heat in some, and too great Cold and Darkness in others?

*B.* Their Bodies, with their several Organs of Sense, are undoubtedly suited and adapted to the different Constitutions and Temperaments of the *Planets*, which are the Extremes, by the same almighty Power, and all-wise Providence, which hath suited our Bodies, &c. to the State of this *Planet* we live on, which is the mean.

*A.* What are the different Dimensions, Revolutions, Densities, Quantities of Matter, Light, Heat, &c. of the six primary *Planets*, we are discoursing of?

*B.* These will be all seen to the best Advantage, and compared in one general View; to that End, I have drawn up a Synopsis of them all together, as you here see, all grounded on Mr. *Whiston's* Calculations, which are the most moderate of any: I have moreover drawn the six primary *Planets* in their true Proportions of Magnitude, on *Plate XV*, fronting p. 187.

*A. Sir,* It is very good; I take it as a great Favour, and humbly thank you.

\* I never yet could be so lucky as to obtain a Sight of these Belts and Spots in Jupiter, tho' I have often endeavoured it with a Tube 12 and 16 Feet. The remarkable Spot discovered by Mr. *Hook*, in 1665, May 9th, at 9 at Night, is that by which the Motion of *Jupiter* about its Axis is determined to be in 9 Hours 56<sup>l</sup>.

of the P. B. W. R. T. S.

MASSACHUSETTS

STATE OF MASSACHUSETTS

IN SENATE

JANUARY 18, 1891

REPORT

OF THE

COMMISSIONERS

OF THE

LANDS

AND

WATERS

OF THE

COMMONWEALTH

OF MASSACHUSETTS

FOR THE YEAR 1890



A SYNOPSIS of divers AFFECTIONS of the *P L A N E T S*.

| T I T L E S.                                                                                                      | SATURN.                               | JUPITER.                             | MARS.                                | EARTH.                             | VENUS.                               | MERCURY.                            |
|-------------------------------------------------------------------------------------------------------------------|---------------------------------------|--------------------------------------|--------------------------------------|------------------------------------|--------------------------------------|-------------------------------------|
| Their <i>Diameters</i> in <i>English Miles</i> - -                                                                | 67870                                 | 81155                                | 4444                                 | 7964                               | 7906                                 | 2460                                |
| The <i>Circumference</i> of their <i>Bodies</i> - -                                                               | 213112                                | 254908                               | 13960                                | 25020                              | 24823                                | 7724                                |
| Their <i>Superficies</i> in <i>square Miles</i> - -                                                               | 14468430000                           | 20688000000                          | 62032000                             | 199250205                          | 196238000                            | 1900804                             |
| Their <i>Solidity</i> , or <i>Magnitude</i> , in <i>cubic Miles</i> -                                             | 163637700000000                       | 281042300000000                      | 45966600000                          | 264466789070                       | 258445900000                         | 7793273000                          |
| Their <i>mean Distances</i> from the <i>Sun</i> in <i>Miles</i> -                                                 | 777000000                             | 424000000                            | 123000000                            | 81000000                           | 59000000                             | 32000000                            |
| The <i>Diameter</i> of their <i>Orbits</i> in <i>Miles</i> - -                                                    | 1554000000                            | 848000000                            | 246000000                            | 162000000                          | 118000000                            | 64000000                            |
| The <i>Circumference</i> of their <i>Orbits</i> in <i>Miles</i> -                                                 | 4881891000                            | 2662280000                           | 773686000                            | 508939200                          | 370636000                            | 201024000                           |
| Their <i>periodical Times</i> - - -                                                                               | 10759 <sup>d</sup> 6 <sup>h</sup> 36' | 433 <sup>d</sup> 12 <sup>h</sup> 20' | 686 <sup>d</sup> 23 <sup>h</sup> 27' | 365 <sup>d</sup> 6 <sup>h</sup> 9' | 224 <sup>d</sup> 16 <sup>h</sup> 49' | 87 <sup>d</sup> 23 <sup>h</sup> 16' |
| The <i>Times</i> of their <i>diurnal Motions</i> - -                                                              | — — —                                 | 09 09 56                             | 01 00 40                             | 00 23 56                           | 00 23 00                             | * * *                               |
| Their <i>daily mean Motions</i> in the <i>Ecliptic</i> - -                                                        | 00° 2' 00"                            | 00° 04' 59"                          | 00° 31' 27"                          | 00° 59' 08"                        | 01° 36' 08"                          | 04° 05' 32"                         |
| The <i>Inclination</i> of their <i>Orbits</i> to the <i>Ecliptic</i> -                                            | 02 30 00                              | 01 20 00                             | 01 52 00                             | 00 00 00                           | 03 24 00                             | 06 54 00                            |
| The <i>Excentricities</i> of their <i>Orbits</i> - -                                                              | 54700                                 | 25050                                | 141000                               | 1490                               | 517                                  | 7970                                |
| The <i>Proportion</i> of <i>Weight</i> on their <i>Surfaces</i> -                                                 | 529                                   | 943                                  | * * *                                | 435                                | * * *                                | * * *                               |
| The <i>Proportion</i> of their <i>Bulks</i> - - -                                                                 | 621350                                | 1064500                              | 170                                  | 1000                               | 985                                  | 30                                  |
| The <i>Densities</i> of their <i>Masses</i> - - -                                                                 | 67                                    | 94 <sup>1</sup> / <sub>2</sub>       | * * *                                | 400                                | * * *                                | * * *                               |
| The <i>Quantity</i> of <i>Matter</i> in each - -                                                                  | 33                                    | 92                                   | * * *                                | <sup>59</sup> / <sub>100</sub>     | * * *                                | * * *                               |
| Their <i>Proportion</i> of <i>Light</i> and <i>Heat</i> - -                                                       | 1 <sup>1</sup> / <sub>10</sub>        | 31 <sup>1</sup> / <sub>12</sub>      | 43                                   | 100                                | 200                                  | 700                                 |
| Their <i>Moons</i> or <i>Satellites</i> - - -                                                                     | 5                                     | 4                                    | * * *                                | 1                                  | * * *                                | * * *                               |
| <i>Proportion</i> of <i>Diameters</i> to that of the <i>Sun</i> 1000                                              | 137                                   | 181                                  | 6                                    | 12                                 | 12                                   | 4                                   |
| <i>Proportional mean Distances</i> - - -                                                                          | 953800                                | 520110                               | 152369                               | 100000                             | 72333                                | 38710                               |
| <i>Greatest apparent Diameters</i> - - -                                                                          | 00' 19" 40'''                         | 00' 24" 12'''                        | 00' 20" 50'''                        | 32' 47" Sun                        | 01° 05' 58"                          | 00' 11" 48'''                       |
| <i>Least apparent Diameters</i> - - -                                                                             | 00' 14" 11'''                         | 00' 14" 36'''                        | 00' 2" 46'''                         | 31' 30" Sun                        | 00' 09" 34'''                        | 00' 04" 04'''                       |
| <i>Place</i> of the <i>Aphelion</i> - - -                                                                         | ♄ 27° 49' 45"                         | ♃ 9° 9' 54"                          | ♂ 0° 31' 54"                         | ♂ 8° 1' 10"                        | ♊ 4° 19' 54"                         | ♄ 13° 7' 54"                        |
| <i>Place</i> of the <i>Node</i> - - -                                                                             | ♄ 21° 49' 54"                         | ♄ 7° 19' 54"                         | ♂ 18° 29' 54"                        | * * *                              | ♊ 14° 25' 54"                        | ♄ 15° 1' 54"                        |
| The <i>greatest Elongation</i> of the <i>inferior</i> , and<br><i>Parallax</i> of the <i>superior Planets</i> - - | 6° 0' 00"                             | 11° 5' 00"                           | 14° 0' 00"                           | * * *                              | 46° 41' 00"                          | 22° 46' 00"                         |



C H A P. V.

Of COMETOGRAPHY, or the PHILOSOPHY  
of the COMETS.

A. **H**AVING thus pretty largely conversed with the *Planets*, and viewed their various Natures, Numbers, and Affections; let us next, if you please, discourse of the *Comets*: And, in the first Place, pray tell me what the proper Meaning of the Word *Comet* is?

B. COMET is a *Greek* Word, derived of the Verb *κυμαίνω*, to have long Locks, or wear long dishevelled Hair; because a *Comet* seems to have as it were a long hairy Tail.

A. Pray what is the Matter or Substance of a *Comet*?

B. Sir *Isaac Newton* saith, the Bodies of *Comets*, or blazing *Stars*, are solid, compact, fixed, and durable Substances; and are, indeed, but a different Kind of *Planets*, which move about the Sun, and shine by the Light of the Sun-Beams reflected from them \*.

A. How many Sorts of *Comets* are there?

B. COMETS receive a Division or Distinction on Account of the different Form of their Tails: Thus,

*Cometa Crinitus*, which casts forth Beams like *Hair* around it.

*Cometa Barbatus*, having a Tail resembling a *Beard*.

*Cometa Ensiformis*, having a Tail like a *Sword*.

\* *Principia Philos.* Pag. 508.

*A.* Why, *Sir*, do the *Comets* appear with blazing Tails, and no other Planet or Star do so?

*B.* This seems owing to some peculiar unctuous Matter in the Bodies of the *Comets*; which, by their Approach to the *Sun's* Body, is prodigiously heated, rarefied, and made to fly off in a fiery Vapour, on that Side opposite to the Sun, in the Form of a long Tail, growing wider and thinner (as all fummy Vapours do) the farther it proceeds from the *Comet's* Body.

*A.* Then you suppose, I find, that the *Comets* revolve about the Sun, as well as the Planets; but, pray, in what Kind of Orbs do they move?

*B.* They move, indeed, in stated Periods of Time about the Sun, in Orbs vastly eccentric and elliptical, but some more, and some less so, as their Periods are longer or shorter. The Forms of three remarkable cometary Orbs are described in the Solar System before-going\*.

*A.* In what Parts or Regions of the Heavens do they move?

*B.* Far above our Atmosphere, or Region of Air: Yet when they come nearest the Sun, they all descend within the Orb of *Saturn*; and those which come nearest to the Sun, are nearer than even *Mercury* itself: Then from the Sun, they make amazing long Excursions through the vastly distant Regions of the Universe all Manner of Ways, and across the Orbs of the Planets.

*A.* How far do you think some of the most erratic *Comets* may rove from the Sun?

\* See the parabolic Orbs of 21 *Comets* described in Mr. *Whiston's Solar System*, or the same epitomized in Dr. *Desaguliers's Courses*, Vol. I.

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B. Dr. *Halley* has determined the longer Axis of the Orb of that *Comet*, which appeared in 1680, and whose Period is 575 Years, to be 1382957 Parts, of which the mean Distance of the Earth from the Sun is 10000; wherefore supposing this mean Distance to be 81000000 *English Miles*, then the Length of that *Comet's* Orb will be 11201951700, *i. e.* above eleven thousand and two hundred Millions of *English Miles*; which may be esteemed as so far beyond the Sun, the Sun being, as it were, in the very Orb itself at the hithermost End.

A. The *Comets* approaching thus near the Sun, must surely be very hot; and receding again to such a prodigious Distance, must there be again very cold: Is it not thus, *Sir*?

B. Yes, most certainly: *Sir Isaac Newton* has computed the Heat of the aforesaid *Comet*, when nearest the Sun, to be 2000 Times hotter than red-hot Iron: But Bodies thus heated preserve their Heat a long Time; it is computed that a Ball of Iron, as big as the Globe of our Earth, would, if red-hot, require 50000, or fifty thousand Years to grow cold in; but the Bodies of *Comets* being vastly greater than our Earth, can therefore never be cold, at their greatest Distance from the Sun \*.

A. And,

\* Since the Distance of the *Comet Ann. 1680, Decem. 8*, when it was in its *Perihelion*, from the Sun, was to the Distance of the Earth at that Time from the Sun, as about 6 to 1000, the Heat of the Sun at that Time at the *Comet* was to the Heat of our Summer Sun, as 1000000 to 36, or 28000 to 1. But the Heat of boiling Water is about three Times as great as the Earth conceives from the Summer's Sun; and the Heat of red-hot Iron is three or four



*A.* And, pray, can the Places of the *Comets* be found in the *Zodiac*, as those of the *Planets*, by Calculation?

*B.* Yes: That indefatigable Improver of all Arts, Dr. *Edmund Halley*, has, by the Labour of many Years, compiled a Set of Tables, whereby the Places of above 20 *Comets* are to be determined for any given Time: A Work which will endure for ever; and for which all future Astronomers must acknowledge themselves indebted to this great Man \*.

*A.* Pray what do you farther observe concerning those Bodies?

*B.* We may observe, that as they are discovered of late Years to be hard solid Bodies, encompassed with an Atmosphere, and revolve about the Sun in stated Periods of Time; therefore they are a Part of the *Mosaic* Creation, as well as other Planets, and are not to be reckoned Meteors, casually kindled and fleeting in the Air, as the ancient Philosophers dreamed.

*A.* Well, to end the Discourse of *Comets*, pray tell me, in the last Place, to what Use or Purpose they may serve?

*B.* Some conjecture they are appointed to demolish planetary old Worlds, and to supply Ma-

Times as much as that of boiling Water; and therefore the Heat which dry Earth would conceive from the solar Rays at the Comet in *Perihelio* is near 2000 Times greater than red-hot Iron. And therefore with so great a Heat *Vapours*, *Exhalations*, and all *volatile Matter*, must needs be immediately consumed and dissipated. *Newton's Princip.* in Loco citato.

\* This *Synopsis* of *Cometary Astronomy* by Dr. *E. Halley* is excellently well explained by Mr. *Whiston*, at the End of his *Geom.* Lectures.

terials again for building them anew; others, that they are so many Hells to punish the Damned with perpetual Vicissitudes of intolerable Heat and Cold; but all is uncertain\*.

C H A P. VI.

ASTROGRAPHY, or the PHILOSOPHY of the fixed STARS.

A. **D**O you not mean by *Astrography*, the Science or natural Knowledge of the fixed Stars?

B. Yes: It being composed of the Greek Words, ἀστρον, a *Star*, and γραφή, a *Description* (as hath been said often before;) whence it signifies a *philosophical Description of the fixed Stars*.

A. Please to tell me why they are called fixed Stars?

B. They are so called, in Opposition to the *Planets*, or moving Stars; because these always

\* The latter is Mr. *Whiston's* Opinion, as may be seen in his *Astronom. Princip. of Religion*.

See much more of Comets in *Newton's Prin. Math. Philos.* Lib. III. Prop. 40, 41, 42. Dr. *Gregory's Astronemy*, Book V. Dr. *Keill's Astron. Lect.* 17. Dr. *Halley's Synop. of the Astron. of Comets*. Mr. *Whiston's Astron. Principles of Religion*. Mr. *Derham's Astro-Theology*. *Robault's Physics*, Part II. Chap. 26. with Dr. *Clarke's* Notes thereon. *Joan. Clerici Physica*, Lib. I. Cap. 11. *La Bibliothèque des Philosophes*, Tome prem. Page 362. *L'Histoire Naturelle de l'Univers*, Tom. I. Partie I. Chap. 2. *Institutio Philos.* Tom. III § 2. Dr. *Cheney's Philos. Princip.* Part I. Chap. 5. § 18. *Regnault's Philos. Conversat.* Vol. III. Convers. 20. Page 283. with Mr. *Dale's* Notes thereon. The Authors cited in *Johnson's Philos. Questions*, Page 129, 30, 131. Dr. *Harris's Lexicon*, and *Chamb. Diction.* under the Word *Comet*. Dr. *Desaguliers's Course*, Vol. I. Page 409, 410, 411.

keep the same Place in the Heaven, and do not seem to move for many Ages together.

*A.* But by this, I think, you imply they have some Motion ?

*B.* The Motion of the fixed *Stars* is very small, not exceeding 50'' of a Degree in a Year, or one Degree in 70 Years ; and therefore to compleat one Revolution of a Circle is required 25920 Years ; after which Time the *Stars* all return again to their former Places : This Period of Time they called the *Great* or *Platonic Year*, in ancient Times ; and imagined, when it was finished, all Things would begin again anew, and return in the same Order they do now.

*A.* I understand by what you said of the diurnal Rotation of the Earth, that the Motion of the *Stars* from *East* to *West* each Night, is only an apparent one ; but the Motion you speak of now, I presume, is a *real* and *proper Motion of the Stars* ; is it not ?

*B.* No, *Sir*, even this is not *real*, but *apparent* ; being occasioned by a certain contrary equal Motion of the Earth, arising from the *spheroidical* Figure thereof, which Figure also ariseth from the Rotation of the Earth about its Axis \*.

*A.* Thus much of the Motion of the fixed *Stars* ; pray what do you think of their Number, is it not infinite ?

\* This is confirmed by Experiment ; for if a large Armillary Sphere be made to turn very swiftly about an Axis, the said Sphere will very visibly swell out and become more extended in and about the Equatorial Parts, and at the same Time be contracted and sink from the Poles ; which will occasion the Sphere to put on an *oblate* or *spheroidical Form*, such as is here ascribed to the Earth on Account of its rapid diurnal Motion. See Dr. *Keill's Astron.* Lect. VIII. Page 77, 78, 79.

*B.* If



*B.* If they are not infinite, they are certainly innumerable; for with a good *Telescope* they appear Millions beyond Millions, 'till by their immense Distance they evade the Sight as assisted with the best Instruments; but then do not mistake, those which are visible to your naked Eye, are (in the most serene Night) but a few, not above three or four Hundred.

*A.* No! That is a strange Doctrine! Do not every Man's Eyes declare them innumerable? And doth not the Scripture also affirm the same?

*B.* I know People are not easily persuaded to believe this new Notion of the Number of the *Stars* which are visible, but it is founded on Demonstration; the Eye is deceived by the vehement Twinkling, and confused Appearance of the *Stars*: And as to the Scripture, it speaketh of the *Stars* hyperbolically, or else it meaneth the invisible *Stars*, as well as those that are visible; and then, indeed, they are numberless, as I said before.

*A.* Pray how do you know the Number of the visible *Stars* is so small?

*B.* By astronomical Observations for many hundred Years past, and the Catalogues which have been several Times taken of them.

*A.* Catalogues! what, I pray you, of the *Stars*?

*B.* Yes, the fixed *Stars* have been long since registered in the Records of Astronomy: *Hipparchus*, the *Rhodian*, about 120 Years before Christ, was the first who made a Catalogue of the *Stars*; his contained 1022: After him, *Ptolemy* enlarged this Catalogue to 1026: *Ulug Beighi*, the Grandfather of *Tamerlain* the

*Great*, made a Catalogue of 1017 Stars: *Tycho* determined the Places of 777 fixed Stars, and reduced them to a Catalogue: *Kepler's* Catalogue contained 1163: The Prince of *Hess's* Catalogue was of 400 Stars: The *Jesuit Ricciolus* enlarged *Kepler's* Catalogue to 1468: It is said also that one *Bayerus* had described the Places of 1725: After this, *Hevelius* of *Dantzick* composed a new Catalogue of 1888: But the largest and most compleat Catalogue ever yet published of the fixed Stars, is that of Mr. *Flamsteed*, in his *Celestial History*, which contains near three thousand Stars; all whose Places and Situations are far better, and more exactly determined in the Heavens, than the Position of many Cities on Earth through which Travellers daily pass \*.

A. Well, considering the many hundred of Years Observation on the Stars, and the various Catalogues made thereof which you have now related; and considering the most compleat contains not above 3000 Stars, tho' assisted by the longest and best Glasses; I am obliged to acknowledge my erroneous Notion of the great Number of the visible ones; and shall next, if

\* What I have here asserted concerning the small Number of the visible Stars, and the Catalogues of them, is upon the Authority of no less a Man than that excellent Astronomer Dr. *Keill*. See his *Astronom. Lect.* VI. Page 51, 52, 53, 54, where he has these Words—Of the 3000 Stars in Mr. *Flamsteed's* Catalogue, it is seldom that a very good Eye can reckon more than one Hundred together. And, if I mistake not greatly, the famous *Flamsteed* himself does, in his *Historia Cœlestis*, positively assert, that the naked Eye cannot discover above 384 Stars in the sereneest Night, in both the Hemispheres. And the Reader, if he thinks fit to take on him the Trouble of counting the visible Stars, will need no other Reason to convince him of his Mistake in this Matter.

you please, ask your Opinion concerning their Distance from us?

B. Their Distance! Alas, you can hardly enquire about a Thing more unknown, or more incredible, than what is but imperfectly known thereof; however, to satisfy you, take the following Account. The famous *Hugens* found the brightest, and largest, and, of Course, the nearest of all the fixed *Stars*, viz. *Syrius*, to be in Appearance 27664 Times less than the Sun; and since their Distances are greater, as their Magnitudes are lesser, therefore this *Star* must beat the Rate of 2000000000000, *i. e.* above two Millions of Millions of *English* Miles; which is so very great, that a Cannon-Ball would spend almost 700000, *i. e.* seven hundred Thousand Years in passing through it; and it is very probable, that all fixed *Stars* are equally distant from each other, in Proportion to the Distance of the nearest of them from our Sun.

A. What are the Grounds of this your Opinion?

B. By the Smallness, of their Appearance thro' the best Glasses, and the different Degrees thereof, I am induced to believe, that they are not only as far distant from each other as from our Sun; but also, that each fixed *Star* is a Sun, surrounded by a System of *Planets* and *Comets*, and those again furnished with different Numbers of Moons, all in the same Analogy, Order, and Proportions of Number, Size, and Glory, as we behold in those of our own Solar System.

A. O! amazing and stupendous scene! Suns without Number; and Worlds turning up upon  
I Worlds!



Worlds! Systems of moving Orbs immensely great, yet invisible to our Eyes; all inhabited, and dispersed thro' all the distant Realms of universal Space! I am almost lost, yea, quite confused in my Conceptions; but, pray, on what does such a glorious *Hypothesis* depend?

*B.* On Ratiocination, and divers astronomical Observations? We reason thus; our Sun shineth by its own native Light, so do the *Stars*; *ergo*, they are Suns. The Sun at the Distance of a fixed *Star* would appear no larger than a *Star*; *ergo*, a fixed *Star* may be as large as the Sun. None of our Planets at that Distance could be seen at all; *ergo*, each *Star* may have a System of Planets, tho' unseen. God hath made nothing in vain (*Axiom I.*) but nothing is more vain than to pretend Myriads of unseen *Stars* were made to twinkle unheeded in the unseen, unknown Regions of the Universe; *ergo*, they severally serve the noble Purposes of Light and Heat for the Planets of their Systems. As to Observation, it is well known how *Stars* appear and disappear after certain Intervals; what can this be but the Almighty's Hand extinguishing old, and kindling new Suns? Demolishing old, and erecting new Systems of Worlds? And such undoubtedly was the Case of our World, and planetary System, in the *Mosaic* Creation. Our Sun just made, would have been a new fixed *Star* just appearing to an Eye in any of the nearest *Stars*; some of our *Comets* also may there appear new *Stars*, when in their *Aphelia*, but in their Return to their *Perihelia*, disappear again: Thus also some

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of our new *Stars* may be, and doubtless are, *Comets* (belonging to some Sun) in their utmost Excursions, which upon their Return disappear again: These new and extinguished *Stars*, are generally in the *Galaxy*, or Milky-way; but why there more than elsewhere, unless because those Parts, being replenished with a far greater Number of Suns, give of Course more frequent Occasions of these *Phænomena*. Also it is well known, that the *Milky-Way* hath its Complexion from the united Lustre of an infinite Number of fixed *Stars*, or *Suns*, in those Parts of the Expanse, which go by that Name: From all this it appears, that the Hypothesis of a Plurality of Worlds is rational, worthy a Philosopher, and greatly displays the Wisdom, and redounds to the Glory of the great Creator and Governor \*.

A. I

\* 1. A new Star is said to have been observed by *Hipparchus*, but its Place in the Heavens was not left upon Record.

2. On *November* the 8th. 1572, a new Star was observed to appear in the *Chair of Cassiopeia*, by *Cornelius Gemma*; it was seen by *Tycho Brahe* the 11th of the same Month, and in *March* 1754 it became extinct.

3. In *Ann.* 1640, *Sept.* 30, the Scholars of *Kepler* saw a new Star near the right Leg of *Serpentarius*, which gradually disappeared, and was wholly invisible *Jan.* 164 $\frac{1}{2}$ . Note, These two appeared, with the Lustre of *Venus* or *Jupiter*, and not as the following; and are therefore thought to be of a different Species.

4. In the Year 1596, *Aug.* 3, *David Fabricius* gives the first Account of the *Stella Maria*, or wonderful Star, in the Neck of the *Whale*; which has been since found to appear and disappear periodically, its Period being seven Revolutions in six Years, and is never entirely extinguished.

5. In the Year 1600, *William Janssonius* discovered another new Star in the Neck of the *Swan*. This in Time became so small, as to be thought to disappear entirely, till the Years 1657. 58, and 59, when it recovered its former Magnitude; but it soon after decayed, and is now one of the least Size.

6. In

*A.* I now see no Reason to hesitate about the Truth of this new and noble Doctrine; which so enlargeth our View of the wonderful Works of infinite Wisdom, by putting the Universe

6. In the Year 1670, July 15, O. S. *Hewelius* discovered a new Star, which in *October* was so decayed, as to be scarce perceptible. In *April* following it regained its Lustre, but wholly disappeared about the Middle of *August*. In *March* 1672, it was seen again, but very small; since when, it has been no farther visible.

7. The sixth and last new Star was discovered by Mr. G. *Kirch*, in the Year 1686, which returns periodically after the Space of  $404\frac{1}{2}$  Days. And these are all the remarkable new Stars for 160 Years past.

8. There are in the Heavens several *lucid Spots*, called *Nebulæ*, from their *misty Appearance*; they appear to the naked Eye as a dim fixed Star, but thro' a Telescope they appear a broad illuminated Space of *Æther*; in some of which there is a small Star, in others more. Of these *Nebulæ* there are six discovered, viz.

9. The first and most considerable in *Orion's Sword*, at present, is in  $\Pi$   $19^{\circ} 0'$ . South Lat.  $28^{\circ} 45'$ . About the Year 1661, another was discovered in *Andromeda's Girdle*. Its Long. is  $\Upsilon$   $24^{\circ} 0'$ , and Lat. N.  $33^{\circ} 20'$ .

10. The 3d was discovered in the Year 1665, and is in Long.  $\Psi$   $4^{\circ} 30'$ , and Lat. S.  $0^{\circ} 30'$ .

11. The 4th was discovered by Dr. *Halley*, 1677, in the Southern Hemisphere, and never rises in *England*.

12. The 5th was discovered by Mr. *Kirch*, in 1681. Its Long. is  $\Psi$   $9^{\circ} 0'$ , Lat.  $17^{\circ} 10'$  North.

13. The 6th and last was discovered by Dr. *Halley*, in 1714; its Place is near  $\mathfrak{M}$   $26^{\circ} 30'$ , with  $57^{\circ} 0'$  N. Latitude. See the *Phil. Transf.* N<sup>o</sup> 346, 347, and several other Numbers.

14. The Constellation called the *Pleiades*, or seven Stars, contains no less than 70 or 80 Stars visible in the Telescope; and when I had placed a large Telescope against one of the *nebulous* Stars, the Glass was so full of very small Stars, that they could not be numbered. From all this, I think it is perfectly certain, that the whole Universe is replete with numberless Worlds, and Realms of Light of eternal Day, which are intercepted from our Sight by the dusky Regions of our Planetary System.

15. See more on this Subject in Bishop *Wilkins's World in the Moon*. *Fontenelle's Plurality of Worlds*, Even. V. *Hugens's Planetary System*. Mr. *Derham's Astro-Theology*, Introduction; and various other Writers of Astronomy.

into



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into Signification and Harmony, and peopling the same throughout with rational Beings : How will Posterity bless the divine Discoveries and Labours of these Ages, wherein the dark and barren Wilds and Deserts of indefinite Space have been enlightened by such Millions of Suns ; stored and planted with such Myriads of Planets ; and cultivated by such endless Numbers of Inhabitants of every Kind !



T H E

THE  
*Philosophical Grammar:*  
Or, VIEW of  
Modern Philosophy.

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PART III.

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AEROLOGY:

CONTAINING,

- I. The Philosophy of the *Atmosphere*, or *Air*.
- II. The Philosophy of the *Winds*.
- III. The Philosophy of the *Meteors*.
- IV. The Philosophy of *celestial Appearances*.

Explaining what is hitherto known of their *Nature, Causes, Properties, and Effects*.

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CHAP. I.

Of AEROLOGY in general, or the PHILOSOPHY of AIR, shewing its wonderful NATURE, PROPERTIES and EFFECTS.

A. PRAY, Sir, what is the original Signification of *Aerology*?

B. It is a Word compounded of *ἀήρ*, *Air*, and *λόγος*, a *Discourse*; and therefore imports a philosophical *Discourse* of the *Air*.

A. What are we to understand by *Air*?

B. That invisible fluid Substance which encompasseth the Earth on every Side, which contains.

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tains the Vapours, Clouds, and other Meteors, and in which all living Creatures breathe; the whole Body of which is called the *Atmosphere*.

A. Please, Sir, to let me know why it is called the *Atmosphere*?

B. From the two Greek Words, ἀτμός, a Vapour, and σφαῖρα, a Sphere; so that *Atmosphere*, in native *English*, is a round Body of Vapours; and such is the *Air* surrounding the Earth, as being constantly replete with Vapours exhaled by the Sun's Rays.

A. What are the principal Properties of the *Air*?

B. These which follow: 1. The *Air* is fluid, yet cannot be congealed like Water. 2. It is pellucid or transparent to that Degree, as to be invisible. 3. It may be rarefied and condensed. 4. It is endued with an elastic Power or Force. 5. It hath Weight or Gravity. 6. It hath proper Bounds or Limits, and is not infinite. 7. It is necessary to Life, Flame, Sound, Light, &c.

A. How do you know the *Air* is a Fluid?

B. It hath all the Properties of a Fluid; is corporeal, heavy; its Parts yield to any Force impressed, and are easily moved one amongst another; it presseth in Proportion to its Height, and the Pressure is every Way equal: It is evident, therefore, that it ought to be reckoned a Fluid.

A. What is the Reason the *Air* is so transparent, as to be invisible?

B. Because of the great Porosity thereof; the Pores and Interstices of *Air* being so very great and large, it admits the Light not only in right Lines, but in such great and plentiful Rays, that  
the



the Brightness and universal Lustre thereof, not only renders the *Air* diaphanous, but entirely hinders the Opacity of the very small Particles of *Air* from being at all seen; and therefore the whole Body of *Air* must consequently be invisible.

*A.* You observed next, the *Air* hath the Property of being rarefied and condensed; pray how is this demonstrated?

*B.* That *Air* may be rarefied, is proved several Ways; as thus, if you take a Bladder, entirely empty as you think, and tie its Neck with a Thread, and lay it before the Fire, the Heat will so rarefy the little inclosed *Air*, as to make it extend the Bladder to its utmost Stretch, and, if continued, will break thro' it with the Report of a Gun: Also, that *Air* may be so condensed by Art, as to take up but  $\frac{1}{80000}$  Part of the Space it possessed before, is proved by various Experiments\*.

\* Since the Air is compressed by the Weight of the incumbent Atmosphere, and the Density of Air is proportionable to the Force compressing it, it follows by Computation, that at the Height of about seven Miles from the Earth, the Air is four Times rarer than at the Surface; and at the Height of 14 Miles, it is 16 Times rarer than at the Surface; and at the Height of 21, 28, or 35 Miles, it is respectively 64, 256, or 1024 Times rarer; and at the Height of 70, 140, and 210 Miles, it is about 1000000, 1000000000000, or 1000000000000000000; and so on in a geometrical Proportion of Rarity, compared with the arithmetical Proportion of its Height. *Newton's Optics, Page 342.*

Most Authors hold Air to be compressible in *Infinitum*. Heat rarefies, and Cold condenses the Air, the most of any Agents whatsoever.

It has been found that Air, by the bare Force of its Spring, will dilate itself into 13000 Times the Space it possesses under the Pressure of the Atmosphere; and since it may be compressed into 60 Times a less Space than that, it is plain it may possess a Space of 780000 Times greater at one Time than another; for  $13000 \div 60 = 780000$ .

*A.* Pray

A. Pray how do you prove the *Air's* Elasticity?

B. By various Experiments of the Air-Pump, and otherwise: One very plain, is thus; an empty Bladder, whose Neck is fast tied, being put into the Receiver, and the external *Air* therein exhausted, the small Matter of the inclosed *Air* will, by its own proper *Spring* or *elastic Force*, gradually expand itself, and at last will so extend the Bladder as to break it: Thus also, the *Air* compressed in the *Wind-Gun* will by its *elastic Force* (being discharged) drive a Bullet through a Board at the Distance of several Yards, in the same Manner as with *Gun-powder*: Yea, Mr. *Boyle* hath found that *Air* by its Spring, or Elasticity, will so far dilate or expand itself, as to take up 13769 Times a greater Space than before: *This Power of Elasticity is as the Density of the Air* \*.

A. Pray

\* 1. The artificial Fountain; or *Jet a'Eau*, is not only a sufficient *Proof*, but a very pretty *Effect* of the *Air's elastic Force*; see *Fig. LIV.* on *Plate XII.* fronting *p. 153.* Where the Vessel ABDE has a Tube or Pipe DB fixed therein, and communicates with the internal Part or Body AB; the Part B is filled with Water, and the other Part A with Air, by Means of an injecting Syringe screwed on at C. The Air thus crouded in and condensed in the Part A, presses very hard on the Water B, and forces it up the Tube to D, where the Cock being turned, it spouts upright with great Celerity, in a small Stream to the Height H, where being broke and divided by the Resistance of Air, it falls down in a *Mist*, or Drops, like Rain. Of these Fountains divers Sorts may be found described in Authors, particularly in Mr. *Step. Switzer's* *Introd. to Hydrostatics and Hydraulics.*

2. To this Property of Air is owing the *Vacuum* made in a Receiver placed on an *Air-Pump*. For when the Air contained in the Barrels *a, a,* is drawn out by the *Emboli c, c,* the Air remaining in the Receiver *o, o,* dilating and expanding itself by this Power, rushes through the Pipe *b, b,* to fill the *Vacuity* of the

M

Barrels,

A. Pray how do you become acquainted with the *Air's* Gravity ?

B. By

Barrels, which is again drawn out, and the Air in the Receiver again dilates to replenish the Barrels ; and by such a Process the Air is rarefied to such a Degree, as to cause most of the Appearances and Effects of an absolute *Vacuum* ; and this is indicated by the *Mercury* rising in the Tube *l* by the Pressure of external Air.

3. I shall here take Notice of that *Parvum Naturæ Miraculum*, (as *Robault* calls it) or little Miracle of Nature ; I mean the *Lachryma* of *Prussia* or *Holland*, sometimes called *Prince Rupert's Drop*, and in common, the *Glass-Tear*. See its Form in *Fig. LV.* on *Plate XII.* fronting *p. 153.* The Manner of making it is thus : With a Tube they take up a little of the melted Matter of Glass, and let it drop thence red hot into a Pail of Water, by which Means it receives its Form, and is solid throughout, except that now and then a few Air-Bubbles may appear therein.

4. This is the *Nodus Philosophorum*, or that which gives Philosophers the greatest Difficulty and Anxiety to account for its peculiar Property, which is, that the biggest Part or Head of the Tear *A* will sustain the Stroke of an Hammer without breaking ; but if the little End or Tail *B* be broke, the whole Tear will fly into Dust at once, with the greatest Violence, and cause considerable Pain to the Fingers which break it.

5. Some particular Circumstances render the Drop incapable of this surprising Property. As, (1.) If the Tear be cooled in the *Air*, it will not break. (2.) Those which are *nealed* will not break. (3.) If they are ground away on a Grind-stone, nothing extraordinary happens. On the contrary, if it be put into an Air-Pump, and there broke, the Effect will be so great as to produce Light.

6. Some suppose this Effect of the Tear is produced by a *fine Air*, which being pent up in the Body of the Tear, and suddenly passing into the open Pores of the broken Tail, runs rapidly into a thousand small Cells, which grow narrower from the Middle towards the Extremities, which the Irruption of the Air drives asunder violently by the Efficacy of its Spring and accelerated Motion. See *Regnault's Phil. Convers. Vol. I. Conv. 24.*

7. Dr. *Clarke's* Opinion is, that Glass being a springy Substance, it is probable the Glass Drop is broke much after the same Manner as a Steel-bow sometimes bursts in Pieces, when it is loosened on a sudden, *viz.* by the too great Celerity and Force of that Motion, which arises from the mutual Attraction of its Parts. For its Parts from the Center to the Circumference seem to be like so many Bows bent. And thence perhaps it is, that after it is burst to Pieces, its Fissures are disposed like



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Fig: LVI.  
Page 179.

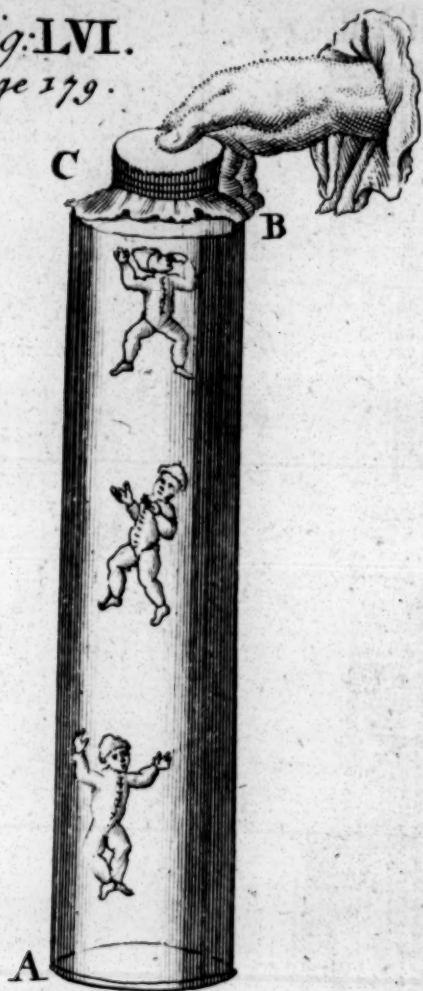


Fig: LVII. Page 180

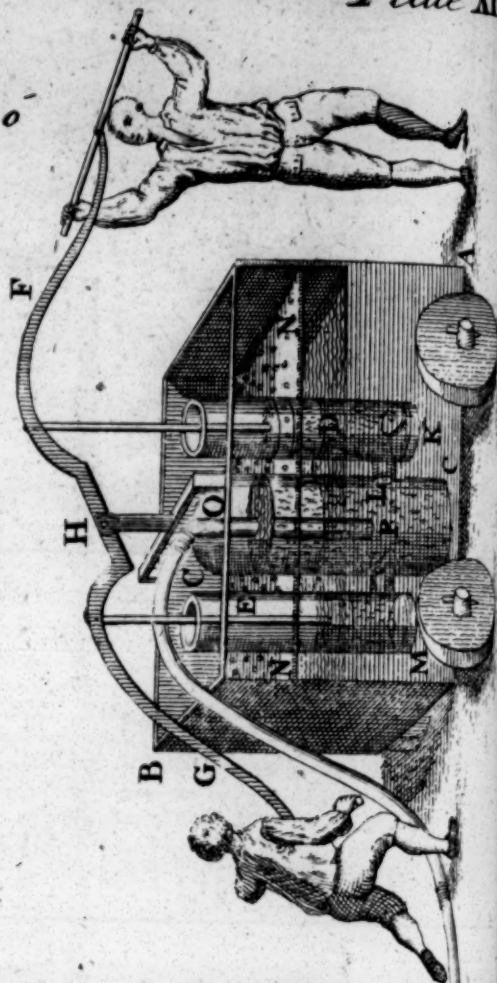


Fig: LVIII.  
Page 180.

Fig: LIX.  
Page 211.

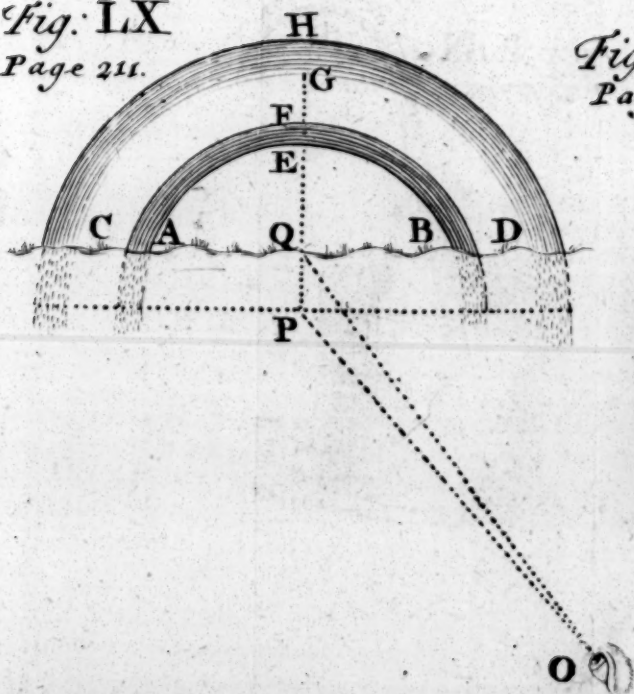
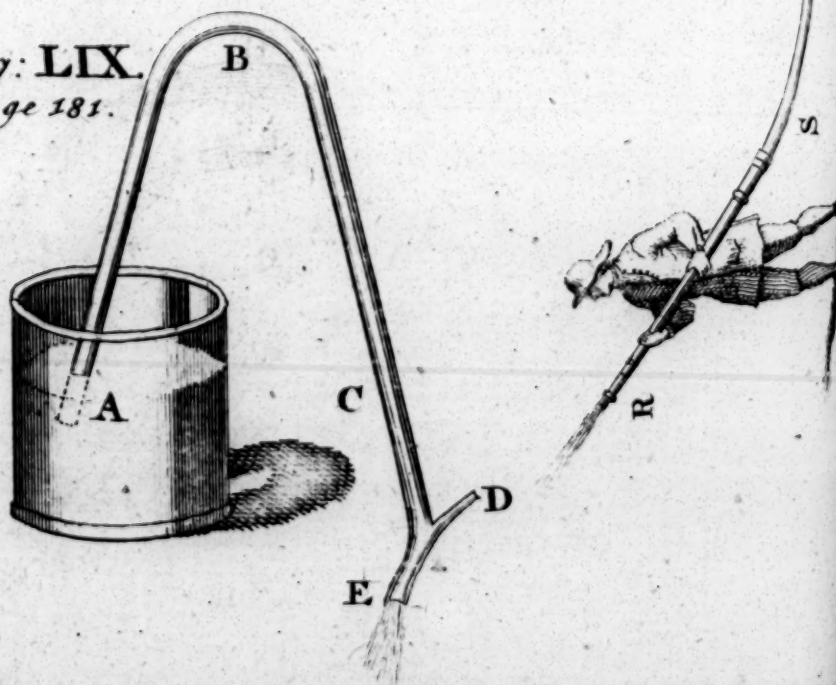


Fig: LIX.  
Page 181.



B. By Experiments of the Air-Pump, Barometer, &c. The Weight of the Air is greater, the nearer it is to the Earth's Surface: The *Mercury*, by the Pressure of the *Air*, is raised in the Barometer to the Height of 28, 29, 30, or 31 Inches; therefore such a Column of *Mercury* is equal in Weight to a Column of *Air* (of an equal Basis) which proceeds from the *Mercury* in the Tube to the uppermost Part of the *Atmosphere*: Also, because *Mercury* is about 14 Times heavier than Water,

so many Radii drawn from the Axis to the Superficies, as Mr. Hooke observed in a Glass Drop covered over with Glue. Notes on Robault's Phys. Part. I. Cap. 22. ad Art. 52. See Hooke's Microg. Observ. 7. and Abundance in Sturmius's Collegium Curiosum.

8. The Phenomenon of the little Glass-Men, &c. ascending and descending in a little Glass Tube of Water, (as AB, Fig. LVI. on Plate XIV, fronting p. 179) at the Word of Command, which looks like a Piece of Conjurat[i]on to the Vulgar, is entirely owing to the Elasticity or Spring of the Air.

9. For these Men being blowed hollow, are thereby rendered specifically lighter than Water, and will swim in it; and having a small Hole in one Foot, and a Bladder being tied over the Top of the Tube, as C, if this be pressed with the Fingers, the included Air by its Spring will equally press the Water, which will enter and compress the Air in the Men, and thereby render them heavier in any Degree. If they are by this Means brought to be of equal Gravity with the Water, they will abide in any Situation therein; if they are rendered heavier by pressing the Bladder harder, they will descend; then the Fingers being taking off, or the Pressure diminished, the Spring of the included compressed Air forces the Water out of the Men, and thus becoming lighter, they ascend to the Top; all which Motions are to be varied in any Degree of Quickness or Slowness the Performer shall please, which renders it the more surprising.

10. The Spring of the Air is of a peculiar Nature, for the Time of its Exertion will not alter it, as it does that of Wood or Steel: For Mr. de Roberval, of the Royal Academy of Sciences, having let his Air-Gun remain charged with condensed Air sixteen Years, found, on discharging the Gun, that the Air's elastic Force was not at all abated, but produced the same Effect as at first. Hist. de l'Acad. 1695. Page 368.



therefore Water will rise in a Tube to 32 or 33 Feet in Height ; and therefore every Square Foot in any Superficies sustains the Weight of a Column of Water of 32 or 33 solid Feet: Now a Cubic Foot of Water weighs about 63 Pounds, hence the Weight of *Air* on every superficial Square Foot, is above 2000 Pound Weight \*.

*A. And,*

\* 1. By the *Gravity of the Air* we receive some of the greatest Advantages of Life ; particularly from thence is deduced the Invention and Construction of the most useful Instruments, Engines and Machines, used in all Kind of Fire and Water-works.

2. From thence arises the Use and Power of that most necessary Engine the *Antlia*, or Pump, which is said to be the Invention of *Ctesibes*, a Mathematician of *Alexandria*, about 170 Years before *Christ*. Of these there are many Sorts ; the common and most useful one consist of a Pipe AB (see *Fig. LVII. on Plate XIV, fronting p. 179*) open at both Ends, of which the End B is set in Water ; toward the lower Part at C is placed a Clack or Valve, opening upwards ; in the Part of the Tube above works a Piston ED just as big as the Bore of the Tube or Pipe, in which also is a Valve opening upwards ; this Part D is called the *Bucket*.

3. Now the Reason of the Pump's Performance is plain ; for when the Piston is forced down, so as that the Bucket D may touch the Frame of the Valve at C, and Water be poured in to fill the upper Part from A to C ; then if the Piston be raised from C to D, it will lift up a Column of Water equal to the Part of the Pipe between C and D, which therefore must run out at the Spout of the Cistern at A.

4. Also at the same Time there is a *Vacuum* made between C and D, which is immediately filled by the Water rushing through the Hole at C, by the Force of the Pressure of the Atmosphere on the Superficies thereof without the Pipe. The Piston being again thrust down, the Water between C and D goes through the Hole of its Bucket, and closing the Valve with its Weight, is raised into the Cistern where the Piston is drawn upwards, and there runs out as before, and thus the Action of the Pump may be continued in raising Water as long as you please.

5. On the *Gravity and Elasticity* of the Air together, depends the Theory of the Fire-Engine in common Use. But this has been improved to produce a continual Stream in the Manner as represented in *Fig. LVIII. on Plate XIV, fronting p. 179*, which I shall here describe. AB is the Frame or Body of the Engine ; CC is a strong metal Vessel, which is close on the Top, but

A. And, pray, what do you infer from thence?

B. Why thence it appears, that if we allow the whole Surface of a Man's Body (of six Feet Stature) to be about 14 square Feet, then the Weight

but communicates with two forcing Pumps, or Barrels D and E, at the lower Part; whose Pistons are worked with a common double Lever FG moving to the Center H; the Engine is filled with Water strained through the Grate NN, which by the Pressure of the Atmosphere is forced into the Barrel D and E, when the Pistons are raised up, and a Vacuum thereby made in them in working the Engine.

6. In the present Figure, the Sucker in the Barrel D is drawn up, and the Water rushing in through the Valve at K, while in the other Barrel E, the Piston is forced down, and the Water forced through a small Passage against a Valve L, which opens and gives it Admittance into the large Vessel CC.

7. The Water being thus forced into the said Vessel continually by the alternate Action of the Pistons, does violently compress the Air in the upper Part of the Vessel at O, which by its Spring re-acts on the Surface of the contained Water, and forces it to ascend the Orifice of a small Tube P fixed to the Side of the Vessel; the upper End of this Tube communicates with a long *leathern Pipe* Q affixed thereto at O, through the Top of which, at R, the Water spouts with great Force in a continual Stream, which is directed by a Person at S, to the Fire, or any other Place, as Occasion requires. All which is plain in the Figure which I have taken from Mr. *Clare's* Plate III. in his Motion of Fluids; though I have seen a much better Construction of this Engine by an Artificer in this City; and wish I had a Draught of that to present instead of this.

8. On this Principle it is, that the *Mercury* or Quicksilver rises to the Height of near 31 Inches in the *Barometer*; for the Pressure of the Atmosphere forces so much Quicksilver into the Vacuum of the Tube as will counterbalance its Power, as is evident from the Construction of this Instrument in Note † in Page 23.

9. The Syphon or Crane has from hence also its Use; see Fig. LIX. on Plate XIV, fronting p. 179. For the End A being immersed in a Vessel of Water, if the Air be exhausted from the Syphon at the Pipe D, the Water in the Vessel, by the Pressure of the Air on its Surface, will instantly rise and fill the Cavity of the Syphon: Now if the other End of the Syphon were at C in an horizontal Level with the End A, then the Pressure of the Air on each End would be equal, and consequently the Water would be sustained in the Tube without running out at C.

Weight of *Air* pressing on the Body of such a Man is equal to 28000 Pounds, or 250 Hundred Weight; that is, 12 Ton and a Half: Also, since the Number of square Miles on the Earth's Superficies is computed 199250205, and in one square Mile are 27878400 square Feet, the square Feet on the Earth's Superficies will be somewhat above 5547800000000000; whence the Weight of the whole *Atmosphere*,

10. But since the Part BE is longer than the Part BA by the Length CE, and the Cylinder of Water CE being far more heavy than the same Cylinder of Air, it is plain the Pressure of the Air, or its Effect at the Point C, is thereby very much weakened and abated, and therefore the *Equilibrium* in the Point B being thus destroyed, the Water will run over and flow towards E.

11. By the *Pressure of the Air* it is that Water in Reservoirs is forced to enter the *Conduit Pipes*, and is thereby carried to any Conduit, House, or other Place, below the horizontal Level of the Surface of the Water in the *Reservoir* or Fountain, be the Distance what it will.

12. The Fire rarefying and attenuating the Air in the Chimnies, causes it to ascend the Funnel, while the Air in the Room, by the *Pressure of the Atmosphere*, is forced to supply the Vacancy, rushes into the Chimney in a constant Torrent, excites the Fire to burn with great Vehemence in Stoves, and buoys up the Smoke aloft in the superior Air.

13. Nor does that common Utensil, the *Bellows*, act on any other Principle than the *Pressure* of the Air; for the upper Part being lifted up, raises the Column of Air off the bottom Part, and thus making a *Vacuum* within, the Air rushes in through the Hole in the lower Part, and being compressed by forcing down the upper, it shuts close the Valve within, is protruded with great Force and Violence through the Pipe or Nose of the Bellows. See a Calculation of this Kind in Mr. *Hales's Statical Essays*, Vol. II. Page 329, 330.

14. The last Effect of the *Air's Gravity* I shall here mention, is the most important of all, as being the immediate Instrument of Life, I mean the Acts of *Inspiration* and *Expiration* in Animals; for in the Dilatation of the *Thorax*, the Air by the *Pressure of the Atmosphere* is forced into the Cavity of the Lungs, which we are then said to *breathe in*, or inspire; but when the Muscles contract, the Air is expelled, and we are then said to *breathe it out*, or expire it. And this alternate Action of the Lungs is maintained by the *Air's Pressure*, and is absolutely necessary to Life.





To front Page 187.

Plate XV.

Mercury Mars Venus The Earth.

see Page 160.

Fig: XXV.  
Page 159.

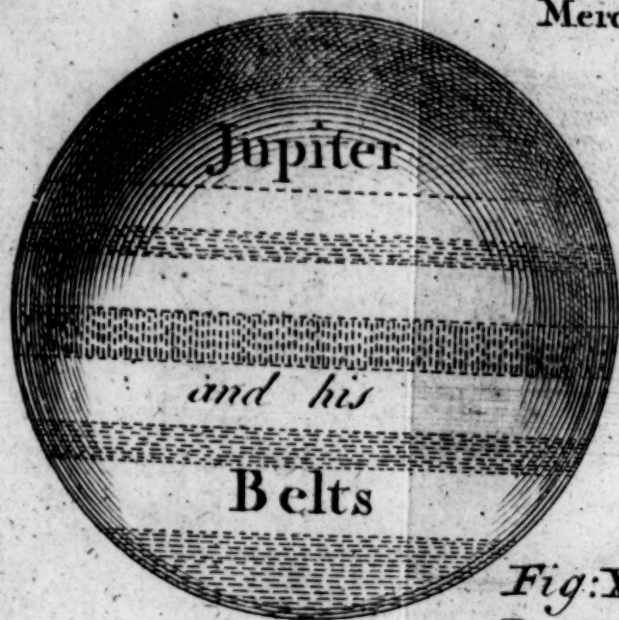


Fig: XXV.  
Page 159.

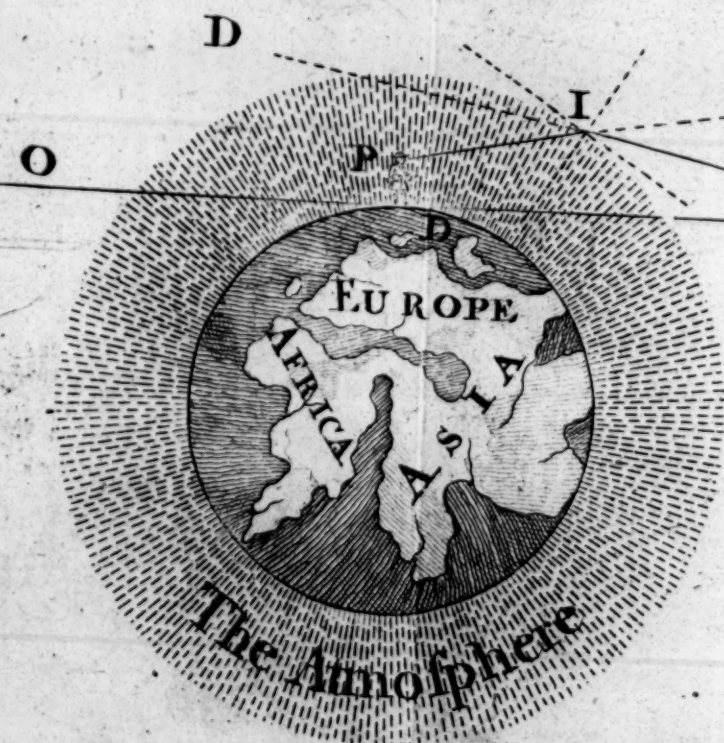
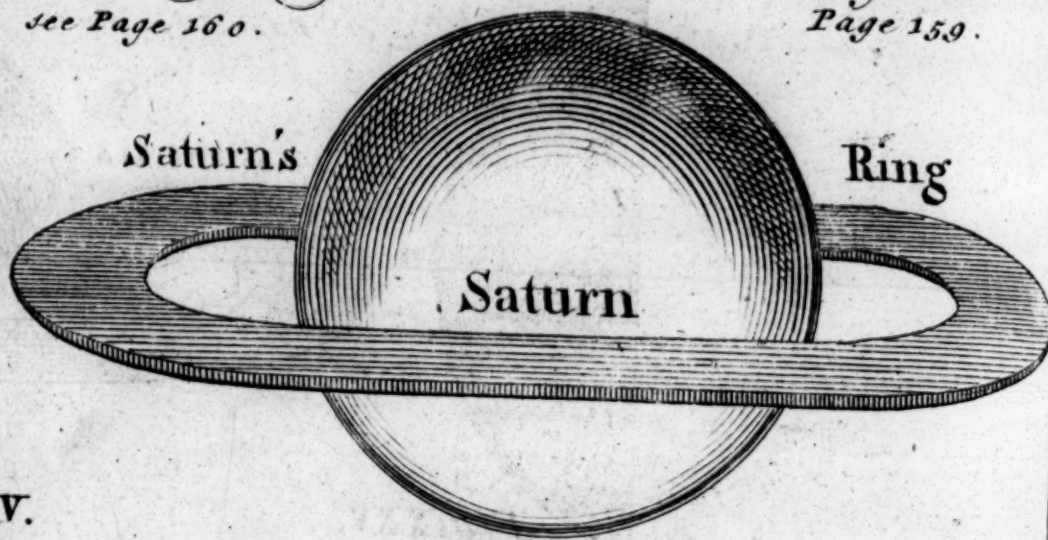


Fig: XXVI.  
Page 187.



H





or its Pressure on the Superficies of the whole Earth, is more than 1109560000000000000 Pounds, or much about 5000000000000000 Tons; that is, the *Atmosphere* compresseth the Earth with a Force, or Power, nearly equal to that of *Five thousand Millions of Millions of Tons*.

A. This is extremely wonderful! But, pray, how happens it that Man, Beasts, Houses, &c. are not crushed to Pieces, if they are pressed with such an intolerable Weight of *Air*?

B. By the *Equilibrium* of the internal *Air*, or the *Air* within all Bodies; which though it be small, and not worth naming, yet can balance, resist, and equiponderate the Force of the external *Air*, (as is proved by various Experiments) how great a Quantity soever it be: The Experiments of the Air-Pump which confirm this are very surprising.

A. I think, Sir, all you have said of the Weight and Gravity of the *Atmosphere*, or *Air*, is full of Astonishment; can you tell any Thing of the *Height of it*?

B. Nothing certainly can be determined about that, because the higher you go, the rarer the *Air* is; and there being no certain Means to determine in what Proportion the *Air* becomes rarer and rarer through the whole Extent thereof, there can of Course be no precise Account of its Altitude: However, they compute the *Air* at the Height of 42 Miles, to be 4096 Times more rare, or thin, than with us; and this being next to nothing, the Height of the *Air* may be reckoned about 40, or 45 Miles.



Agreeably hereto, Dr. *Keill* hath calculated its Height to be 44 Miles by an Observation of the Twilight \*.

*A.* Pray what other very remarkable Properties hath the *Air* ?

*B.* It is not only the Means, but as it were the *Matter of Life itself*, and therefore absolutely necessary.

*A.* How do you shew it to be the Means of Life ?

*B.* By putting certain Animals into the exhausted Receiver ; where it is surprising to see the Effects of withdrawing the *Air* by the Pump on the Bodies of those Creatures : You will thus see *Dogs, Cats, Rats, Mice, &c.* turn up and expire in half a Minute, and look extremely thin and meagre : A *Mole* dieth in one Minute : *Insects*, as *Wasps, Bees, Hornets, Grasshoppers, &c.* in two Minutes seem dead ; and will continue a whole Day and Night without *Air*, and afterwards revive in open *Air* : *Earwigs, Beetles, Snails, &c.* endure the Air-Pump prodigiously ; and *Frogs* will longer preserve their Lives in *Vacuo*, than *Toads* ; yea, those invisible *Animalcules* in Pepper-water, will revive in the open *Air*, after having lain 24 Hours in *Vacuo* †.

*A.* It must be curious, indeed, to see those artificial Deaths and Resurrections in mute Ani-

\* See his *Astronom. Lect.* Page 235, 236.

† See Mr. *Derham's Physico-Theology*, Book I. Chap. I. in the Notes. Mr. *Davenport's* Description of his *Table Air-Pump*. Mr. *Hawksbee's, Gravesande's, &c.* Experiments. *Sturmius's Collegium Curiosum. Stairii Physiol. Exper. Explor.* 14. Sect. 11, 12, 13, 14, &c.

*The wonderful Advantages of the Air.* 185

mals ! But how do you understand *Air* to be the *Matter* of Life ?

B. It is certain *Air* is impregnated with a *vivifying Spirit*, or *Matter*, which is immediately necessary to Life; and that this *vivifying Spirit* is *inflammable*, or proper to feed Fire, and capable of being burnt-or consumed thereby; for it is known by Experiment, that no Creature will live, nor a Candle burn, in *Air* which hath passed through the Fire, and may be called *adust*, or *burnt Air*.

A. Is the *Air* also of Service to Vegetables and Plants ?

B. Yes, in as much as there is a manifest Respiration in Plants and Trees, on which their vegetable Life depends, and is preserved; this is known by numberless Experiments\*.

A. Hath not *Air* an Effect on Bodies which tend to dissolve them ?

B. Yes, the *Air* hath the Faculty of a *Menstruum*, or a Power of dissolving Bodies : It will reduce Crystal-Glasses to a Powder in Time ; so divers Minerals, Earths, Stones, Fossil-Shells, Wood, &c. which, perhaps from *Noah's Flood*, have lain under Ground secure from Corruption ; yet, being exposed to the corrosive Quality of the *Air*, have soon mouldered away ; so Iron, Steel, Copper, &c. may be soon dissolved into a Rust, &c. But such Things are too common to be insisted on, or to want Proof.

\* See Mr. Hales's *Vegetable Statics* throughout. Borelli de *Mot. Animal.* Mr. Millar's *Gardener's Dictionary*, Folio. Dr. Grew's *Anatomy of Plants.* Joan. Clerici *Phys. Lib. IV. Cap. 1, 2.* or an Abridgment of all in my *Philolog. Library*, under the Title *Botany*.

*A.* I have heard you make out already how *Air* is the Means of *Sound*; but, pray, what Advantages of *Light* and *Vision* accrue thereby?

*B.* Very great (perhaps greater than you may be yet apprised of) are the Benefits and Advantages of the circumambient *Air* in these Regards: For *first* were it not for the Rarefaction of the *Atmosphere*, the Heavens by Day would have the Appearance of Night; the Stars, even the smallest, would appear and twinkle; the Sun indeed would appear a great Light in that Part of the dark Firmament where it was; but should a Spectator turn his Back to him, he would see all *Night*, and *Darkness* surround him at Noon-tide. *Secondly*, The Sun at rising and setting would have the same Brightness and Lustre as at Noon-day, and so would be hurtful to our Eyes. *Thirdly*, As soon as the Sun descended the Horizon, we should be in total Darkness, and a cloudy Night would then present us with the blackest Darkness possible. *Fourthly*, As we should have no Twilight by Night, nor shining Lustre of the Firmament by Day, so we should want that Advantage we now enjoy, of not only being blessed with the Light of the Sun when absent, but even of the actual Appearance of the Body of the Sun himself, each Day, before he riseth, and after he setteth.

*A.* What, I beseech you, *Sir*, do you suppose we can see the Sun when he is really under the Horizon?

*B.* Yes, we do, for the Space of some Minutes each Day.

*A.* Pray,



A. Pray, Sir, if possible, let me understand how this can be by a Scheme?

B. I will, and you may very easily apprehend the Truth of this Assertion (though strange) from thence, provided you remember what I said of the Reflection and Refraction of Light, when we discoursed on that Subject.

A. I do remember it very well; pray proceed.

B. Then please to cast your Eyes on *Fig. XXVI.* on *Plate XV*, fronting *p. 187*, which represents the Earth surrounded by its *Atmosphere*: Now let *HO* be the Horizon of a Person at *P*, *S* is the Sun really under the Horizon, from which a Ray of Light *SI* proceeds, and falls on the upper Part of the *Atmosphere* at *I*; this Ray, by the thicker Medium of the *Air*, is bent from its direct Course to *D*, into the oblique one *IP*, and so striketh the Spectator's Eye; the Spectator then will see the Sun in the Direction of this refracted Ray *PI*, viz. at *R*, which is above the Horizon: And thus at some Times of the Year, we see the Sun above the Horizon near 10 Minutes, whilst it is really below it on one Day, taking the Morning and Evening together; at a Medium it is  $6\frac{1}{2}$  each Day throughout the Year, which is as good as  $3\frac{1}{2}$  equinoctial Days in one Year; which is almost a whole Year's Sunshine in a *Century* more than we could otherwise have had.

A. Sir, I perceive it very plainly, and give you abundance of Thanks\*.

C H A P.

\* See large Discourses on this copious Subject in *Boerhaave's Chymistry*, Part I. Page 277 to 304; with *Dr. Shaw's* Notes thereon.

## C H A P. II.

## ANEMOGRAPHY, or the PHILOSOPHY of the WINDS.

A. **H**OW do you derive the Word *Anemography*?

B. From the two Greek Words *ἄνεμος*, *Wind*, and *γραφὴ*, a *Description*; it therefore signifies a philosophical *Description* of *Winds* in general.

A. What is the *Wind*?

B. *Wind* is nothing but a Stream or Torrent of Air, as a River is a Stream or Torrent of Water.

A. What Distinction do the Philosophers make of *Wind*?

B. My Lord Bacon distinguished *Winds* into four Kinds, viz.

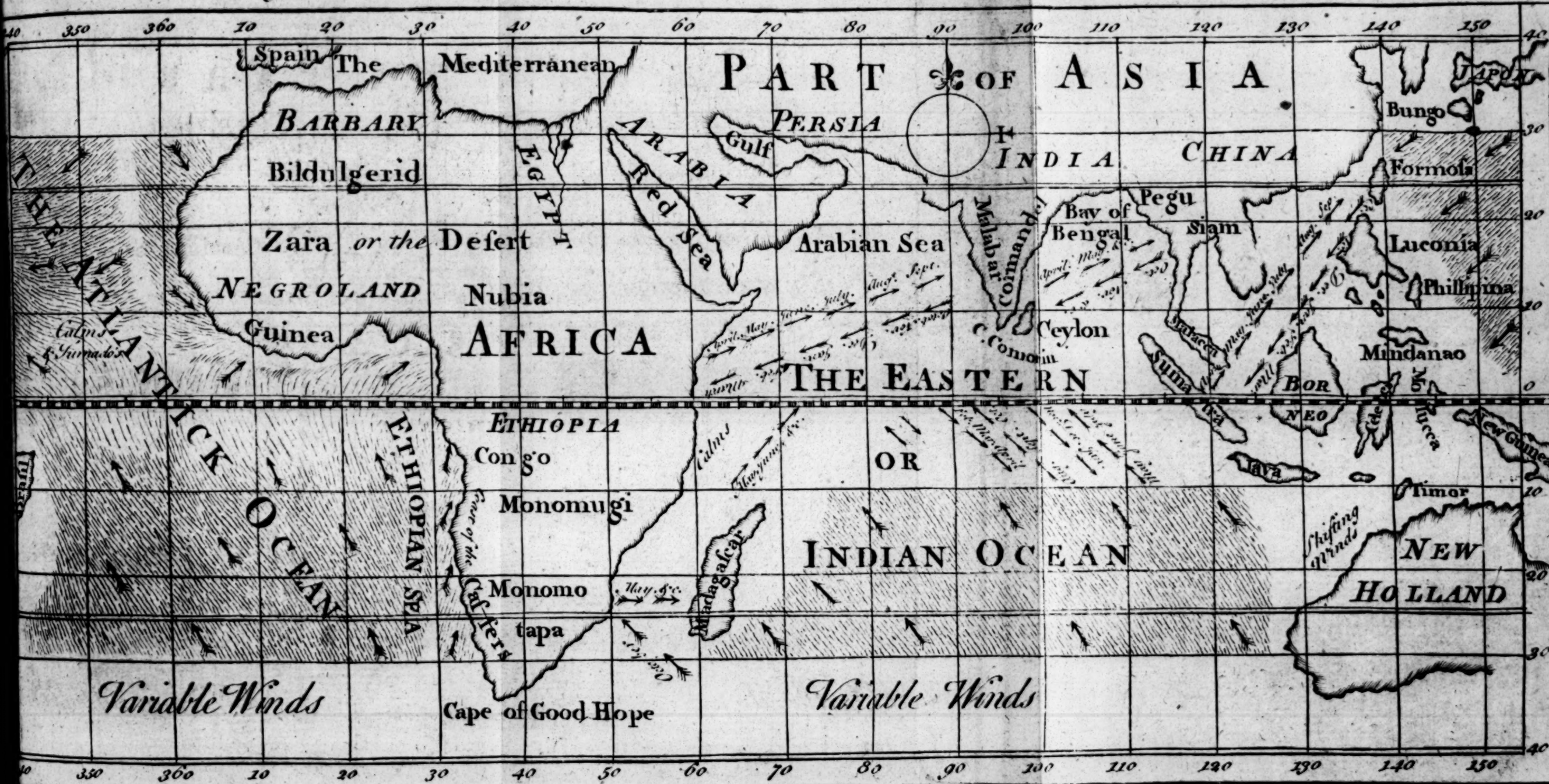
1. General *Winds*, which always blow from the same Quarter.

thereon. Mr. *Clare's* Motion of Fluids. *Newton's* Principia Mathematica. Phil. Naturalis, passim. *J. Robaulti* Phys. Part. III. Cap. 2. cum Annot. Dni *Clarkii* annexis. *J. Clerici* Phys. Part. III. Cap. 1. *Stairii* Phys. Exper. Explor. 19. *Casp. Bartholoni* Specimen Philosoph. Nat. Cap. 12. Mr. *Boyle's* Memoirs for a general History of the Air. *Mariotte de la Nature de l'Air*. *Regnault's* Philos. Conv. Vol. I. Con. 2, 22, 23, &c. *Musschenbroek's* Epitome, Part II. Chap. 22. *Gravesande's*, *Desaguliers's*, *Hawksbee's*, *Worster's*, &c. Courses of Experimental Philosophy. *Cheney's* Princip. of Philos. Part I. Chap. 5. Sect. 28. Relig. Philosopher, Vol. I. Contemp. 17. Mr. *Derham's* Physico-Theology, Book I. Chap. 1. Dr. *Hales's* Vegetable Statics and Hæmastatics. Mr. *Millar's* Gardener's Dictionary, Folio. *Chambers's* Dictionary, and *Harris's* Lexicon, under the Words *Air* and *Atmosphere*; and a great Number of other Authors quoted and referred to in Mr. *Johnson's* Philos. Questions, from Page 84 to 92; and the Philos. Transactions.

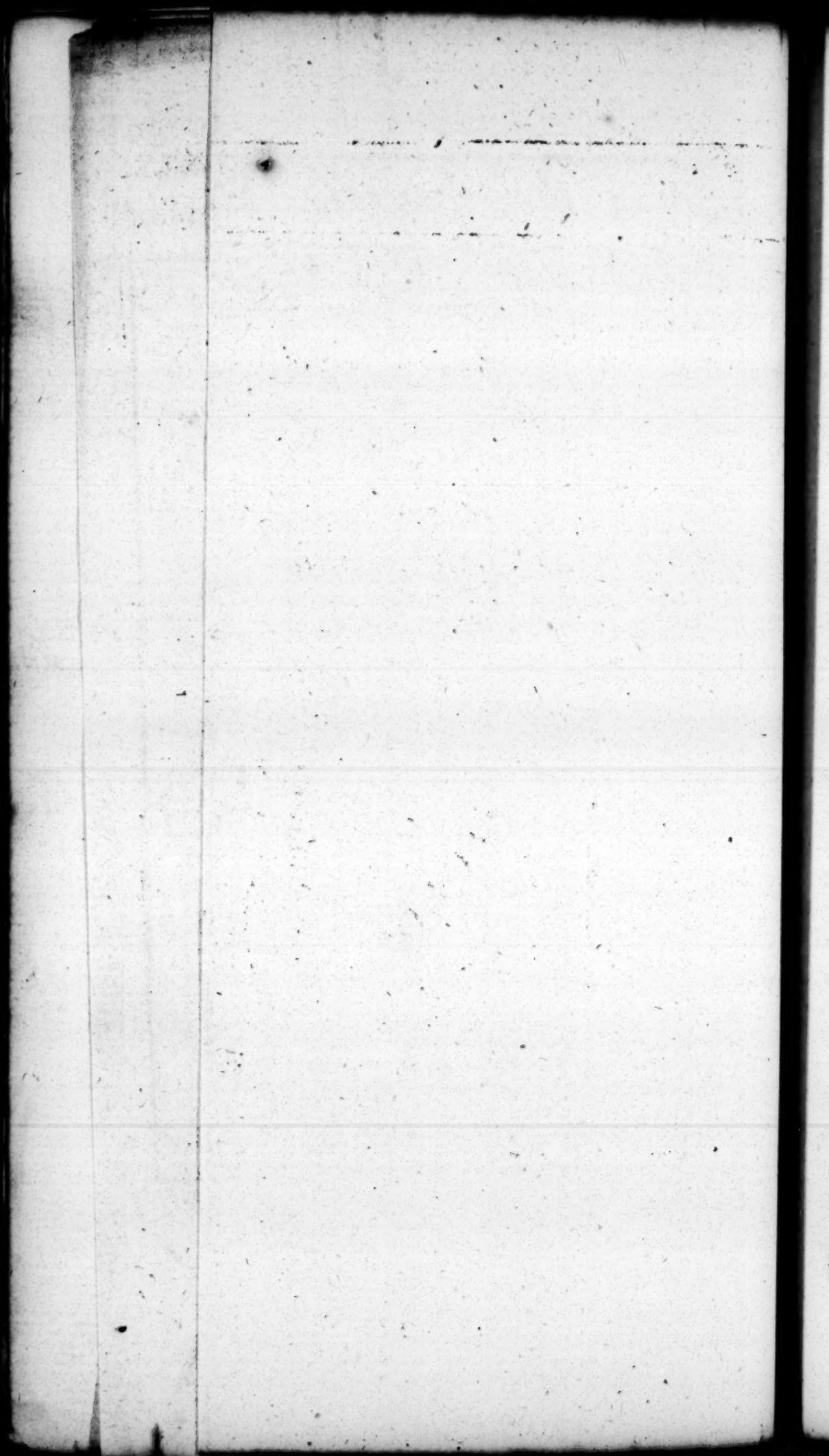
2. Stated



# A View of the General TRADE WINDS and Monsoons or Shifting Trade Winds.







2. Stated *Winds*, which blow only certain Seasons from the same Point.
3. Servile *Winds*, which regard the Region, Time, Season, &c.
4. Liberal *Winds*, which blow indifferently any where, or any how.

But this is not so natural as the following Division of *Winds*, viz.

1. General, or coasting Trade *Winds*.
2. Periodical, or shifting Trade *Winds*, called *Monsoons*.
3. Common, or casual *Winds*, the same as the foregoing liberal *Winds*.

A. What are the different Qualities of *Wind*?

B. They differ (saith my Lord Bacon) not much more in the Points from which they blow, than in the Qualities with which they are diversified; for some are violent, others gentle; some are cold, others hot; some are constant, others mutable; some moisten and dissolve, others dry and thicken; some gather Rain, others are tempestuous and dispel it; and others are serene and smooth.

A. Pray, what are the Causes of *Wind*?

B. Any Thing that can destroy the Equilibrium of the Air, and by acting on some Part with a greater Force, putting it into an Agitation, produceth such a Stream or Current of Air, as we call *Wind*.

A. This is so very general an Account, as gives me but a little more Notion of the Thing than I had before.

B. In

*B.* In all Cases we cannot be acquainted with Particulars ; however, it is pretty certain that divers Things, as Eruptions of Vapours from Sea or Land, Rarefactions and Condensations in particular Places, the Fall of Rains, Pressure of Clouds, &c. may alter the Equipoise, or Balance of the *Atmosphere*, and thereby cause *Winds* more or less : Besides, several Caves, and some great Lakes, emit or send forth *Winds* ; but the most general Causes of *Wind* are *Heat* and *Cold*, as is manifest from the *general* and *periodical Trade Winds* between the Tropics, and thereabouts.

*A.* Pray, what are those *Winds* you call *general Trade Winds* ?

*B.* Such as blow constantly all the Year long from one Quarter ; as from the N. E. or about the *North-East*, on the *North-Side* of the Equator to 30 Degrees Latitude ; and from the S. E. or about the *South-East*, on the *South-Side* of the Equator to about 30 Degrees Latitude, in the *Atlantic Ocean*, *Ethiopian Sea*, the *Indian Ocean*, and great *South-Sea* : These *Winds*, for your better conceiving them, I have represented in the Map adjoined, by dark Lines in the aforesaid *Atlantic*, *Ethiopic*, and *Indian* Seas ; in which you will see divers Arrows shewing the Course of those *Winds*.

*A.* This, Sir, is very helpful, and maketh the Thing easier than your very Words can do : But doth the *Wind* blow constantly in those various Courses and Directions, shewn by the Arrows, within a small Distance of the Coasts of *Africa Westward* ?

*B.* Yes ;



*Of the shifting Trade Winds, or Monsoons.* 191

B. Yes; they are called the general coasting Trade Winds, and always blow on the Points the Arrows shew.

A. But what is the Meaning that I see in the Map several Arrows in clear void Spaces, some pointing one Way, and others the contrary quite, with the Names of the Months abbreviated fixed to them?

B. I will inform you: It is in the *Arabian* Sea, the Bay of *Bengal*, the *Chinese* Seas, by the *Eastern* Coasts of *Afric*, and to 10 Degrees of *South* Latitude in the *Indian* Ocean, that you find those contrary Arrows; and in those Parts you must know the *Wind* blows one half of the Year one Way, and the other Half the contrary Way: These are called the *periodical* or *shifting Trade Winds*, which the Sailors call the *Monsoons*.

A. Then, I suppose, as the Arrows in those several Places shew the various Courses of the *Monsoons*, so their Times of shifting or changing their Points, are denoted by the Names of the Months affixed thereto.

B. Yes, they are, and therefore all those, who sail in these Seas, are obliged to observe the Seasons proper for their Voyages, and in so doing they fail not of a fair *Wind*, and speedy Passage.

A. How do you account for some *Winds* blowing always one Way, and others on contrary Points, in equal Periods of Time?

B. The most sagacious Dr. *Halley* (the Author of all the present Philosophy of *Wind*) gives this Account thereof, viz. That, according

ing to the Laws of *Statics*, the Air which is less rarefied and expanded by Heat of the Sun's Beams, and consequently more ponderous, must have a Motion towards those Parts thereof, which are more rarefied, and less ponderous, to bring it to an Equilibrium, or Balance. And, 2. That the Presence of the Sun continually shifting to the *Westward*, that Part towards which the Air tends, by Reason of the Rarefaction made by his greatest meridian Heat, is with him carried *Westward*; and, consequently, the Tendency of the whole Body of the lower Air is that Way: And thus a general *East-Wind* is formed in the *Atlantic* and great *South-Sea*, perpetually blowing *Westward*.

*A.* But, I observe, by the Arrows, those *Winds* decline from the *East*, *Northward*, on the *North* of the Equator, and *Southward*, on the *South-Side*: Pray how happens that?

*B.* Because near the Line, the Air is much more rarefied than at a greater Distance from it *Northward* and *Southward*; wherefore the Air being towards those distant Parts less rarefied than in the Middle, will consequently tend from the *North* and *South* to the Equator, and so become N. E. and S. E. *Winds*.

*A.* But why are not those *Winds* as universal in the *Arabian*, *Indian*, and *Chinese* Seas, and other Parts between the *Tropics*, which have the same Situation to the Sun, as the *Atlantic*, *Ethiopic*, or great *South Ocean*?

*B.* The Reason hereof is, undoubtedly, owing to their being surrounded by such great Continents, which break the Continuity of the

Oceans;

*The Causes of the Changes of the Monsoons.* 193

Oceans; and from the Nature of their Soil, and the Position of high Mountains, produce those several Variations of the *Wind* in those Places: Thus, the *Winds* set in upon the Land, even from *Westward*, on some Parts of *Guinea*; because the Soil, being sandy, reflects prodigious Heat, which greatly rarefies the Air, and maketh the more cold, and dense, tend thither from the *Western Sea* to restore the *Equilibrium*.

A. And, pray, how is the sudden Change of the *Wind*, to opposite Points, accounted for in the periodical *Winds*, called the *Monsoons*?

B. Thus: The cold and dense Air, by Reason of its greater Gravity, presses upon the hot and rarefied; and therefore the rarefied Air must ascend in continued Streams as fast as it rarefies, and being ascended, it must disperse itself to preserve the *Equilibrium*; and thus, by a contrary current, the upper Air must move from those Parts where the greatest Heat is, and so, by a Kind of Circulation, the N. E. Trade *Wind* below will be attended with a S. W. *Wind* above, and the S. E. with a N. W. above. Now because the Air coming out of the N. E. over vast Continents of Land (which, when the Sun is *Northward*, are intolerably hot; but more cold and temperate, when the Sun is at the *Southern Tropic*) into the *Indian Sea*, is sometimes hotter, and sometimes colder, than that whereby this Circulation is returned out of the S. W. by Consequence, the under Current of Air is one while from the N. E. and another while from the S. W.

A. Do not the Seasons help to determine somewhat of this Matter, in which those Changes happen?

N

B. Yes,



B. Yes, they plainly confirm what I have before said; for in *April*, when the Sun begins to warm those Countries to the *North*, the S.W. *Monsoons* begin, and blow during the Heat till *October*; when the Sun being retired, and all Things growing cooler *Northward*, and the Heat increasing to the *South*, the N.E. *Winds* enter, and blow till *April* again: But yet, why the *Monsoons* change here, and not in the *Ethiopic* Ocean; and also why the Limits of the Trade *Winds* are fixed to about 30 Degrees of N. and S. Latitude, is not so well to be accounted for; and therefore must be left, with several other Intricacies of this Nature, to the Disquisition and Discovery of succeeding Ages.

A. Well, so much then for general and periodical Trade *Winds*; have you any Thing farther to observe of the common and variable *Winds*, incident to all Points and Places?

B. Yes, a few Things touching their Qualities, Velocities, and Extent or Limits.

A. What do you observe of their Qualities?

B. That those *Winds* are dry and cold, which contain the least Quantities of Vapours; those *Winds* gather and generate Clouds, which carry with them great Quantities of Vapours; those *Winds* are hot, which blow from off hot Regions; and cold, which blow from cold ones; those are the most violent, which are agitated by the greatest Force; and the contrary\*.

A. And,

\* See much more on this Subject in Dr. *Halley's* Historical Account of the Trade Winds and Monsoons in *Philos. Transact.* N<sup>o</sup> 183. Lord *Bacon's* History of the Wind. *Bobun's* Discourse

*A.* And, pray, what is discovered of the Velocity of *Wind*?

*B.* It is found by Experience, that the Velocity of *Wind*, in a great Storm, is not more than 50 or 60 Miles an Hour; and that a common brisk *Wind* moves 15 Miles an Hour; and some are so slow as not to move one Mile an Hour.

*A.* In the last Place, what do you observe of the Extent, or Limits, of the *Wind*?

*B.* That it is very uncertain, and little known, unless of the aforesaid Trade *Winds*: The most we know of common *Winds* in their Use, is in cooling and cleansing the Air from all poisonous Contagions, and pestilential Exhalations; and thereby keeping it always pleasant, pure, and healthful; whence appear their absolute Necessity to animal Life, and Conservation of the Universe.

C H A P. III.

METEOROGRAPHY, or the PHILOSOPHY OF METEORS in general, viz. VAPOURS, FOGS, MISTS, CLOUDS, RAIN, HAIL, SNOW, FROST, ICE, THUNDER, LIGHTNING, IGNIS FATUUS, or JACK IN A LANTHORN, FLYING DRAGONS, and such like.

4. I Please myself with the Thoughts of conversing on Subjects, now very pleasant,

on the Origin and Properties of the Wind. *Clare's Motion of Fluids*, Page 237 to 240, and 248 to 265. *Rowning's Comp. System*, Part II. Dissert. 5. And almost all the Authors referred to in the last Note.

and curious, such as what you call the Doctrine of *Meteorography*; but before we proceed, pray let me know what is the true and proper Meaning of the Word *Meteor*?

B. The Greek Word *μετέωρον*, *Meteoron*, is composed of *μετά*, *beyond*, and *αείρω*, *to lift up aloft*; and therefore a *Meteor* implies that which is elevated aloft beyond us in the Air, as *Clouds*, *Lightning*, &c.

A. How many Kinds of *Meteors* do you reckon?

B. Some distinguish them into three Sorts, *fiery*, *airy*, and *watery*.

A. Which do they call *fiery Meteors*?

B. Such as are composed of a *fat sulphureous Exhalation*, kindled by the nitrous Quality or Substance of the Air; and do then exhibit the Appearance of Light and Fire in the Air, as *Lightning*, *Flying Dragons*, &c.

A. What are those called *airy Meteors*?

B. The Wind, and its divers Kinds; but properly speaking, the Wind is no *Meteor* at all, nor are there any *Meteors* which consist merely of Wind.

A. Please to recount me those you call *watery Meteors*.

B. They are such as consist of *Vapours*, and watery Particles, which are separated from one another, and raised by the Sun's Heat, and become modified in the Air into various Forms, as *Mists*, *Clouds*, *Rain*, &c. in abundance.

A. Which do you hold it will be most natural to begin a Conversation withal, of those several Sorts of *Meteors*?

B. It



B. It will certainly be most natural to begin with watery *Meteors*.

A. Well then, to make a Beginning, I observe you said those *Meteors* originally consist of *Vapours*; pray, what are they?

B. *Vapours* are a Company of aqueous or watery Particles, separated from the Surface of the Water, or moist Earth, by the Action of the Sun's Heat; whereby they are so far rarefied, attenuated, and separated from each other, as to become specifically lighter than the Air, and consequently, they rise and float therein; and thus, any Kind of Heat or Fire may cause *Vapours* \*.

A. Pray

\* The Manner in which Heat raises the Particles of a Fluid into the Air, or, which is the same Thing, makes it specifically lighter than Air, is a great Difficulty with Philosophers, who have taken Pains to invent many Hypotheses for the Solution thereof, which may be all seen, with their particular Confutations, in Mr. *Rowning's* Comp. System, Part II. Differt. 6. and the Author himself declines giving any Account thereof on the Principles of the present Philosophy.

But as it is no small Disparagement to the *Atomical* or *Newtonian Philosophy* to suggest its Insufficiency to account for the *Formation, Rise, and Resolution of Vapours into Rain*, I think it proper to propose the following Queries in Behalf thereof. (1.) Does not the received Philosophy teach—That *Fluids* consist of Particles which touch but in few Points, and are united by the Attraction of Cohesion? (2.) That Heat is Fire, and that the Particles of Fire are in a constant and violent Agitation and State of Motion among themselves? (3.) That, since the Power of Cohesion is known to be less than the Power or Force of Action in the igneous Particles, these Particles must divide, separate, and propel the Particles of the Fluid every Way from each other; and therefore, (4.) May not those Particles of the Fluid, which lie in the Surface, be driven upwards beyond the small Sphere of Attraction by the Action of the fiery Particles? (5.) And, then being extremely small, may they not be lighter than the Air on the Surface of the Fluid, and therefore be forced to ascend in it according to the Laws of *Statics*? (6.) Being buoyed up to a

*A.* Pray what *Meteors* are immediately formed of *Vapours*?

*B. Fogs and Mists:* *Fogs* are those Collections of *Vapours* which chiefly rise from fenny, moist Places, which become more visible as the Light of the Day decreaseth; if these are not dissipated, but unite with those that rise from Waters, as Rivers, Lakes, &c. so as to fill all the Air in general, then they are called *Mists*; and often they stink, from a sulphureous Exhalation, or Matter they contain.

*A.* What *Meteors* are next formed of *Vapours*?

*B. Clouds* are the next State of *Vapours*; for they consist only of a Congeries of *Vapours* exhaled from Sea and Land, and raised to that Height in the Air, where they become of equal Weight, or Gravity, with the Air; in those Parts, therefore, they float and swim, and by striking one against another, and mixing one with another, they coalesce, or thicken, and become more dense and weighty; the thinner or rarer the *Clouds* are, the lighter and higher they soar; but

Height where the Air is of equal Weight, will they not be there suspended in the Form of Clouds, according to the same Laws? (7.) May they not there (by the Means above assigned) be condensed and imbodyed, and so become more weighty than the Air, and therefore endeavour to descend thro' it, according to the same Laws? (8.) But descending thro' a Body of considerable Resistance (as the Air is) will they not be again divided and separated into lesser Parts, which being heavier than an equal Portion of Air, will still keep descending in Drops or Form of Rain?

I see nothing unnatural or meerly conjectural in all this, and sure I am, it is all consentaneous to the Principles of the present received Philosophy. If any think the Subject of these Queries deficient in regard of the Purpose, they are to shew it,

the

*Of Clouds, their Colours, Height; of Rain.* 199

the more dense they are, the weightier, and the nearer they ride to the Earth.

*A.* Pray how high do you judge the *Clouds* to fly?

*B.* From about a Quarter of a Mile to a Mile; it is very common for Persons, by climbing very high Mountains, to get above the *Clouds* and see them swim beneath them, cleaving against the Mountains they are on \*.

*A.* That must be very curious to observe; but whence the various Figures and Colours of the *Clouds*?

*B.* The wonderful Variety in the Colours of the *Clouds*, is owing to their particular Situation to the Sun, and the different Reflections of his Light: The various Figure of the *Clouds* results from their loose and volube Texture, revolving into any Form, according to the different Force of the Winds.

*A.* That *Rain* is produced from the *Clouds* we all know; but in what formal Manner doth it happen?

*B.* Thus: When various Congeries of *Clouds* are driven together by the Agitation of the Winds, they mix and run into one Body, and thus dissolve and condense each other into their former Substance of Water; also the Coldness of the Air is a great Means to collect, compact, and condense *Clouds* into Water: The Water thus produced of the *Clouds*, being heavier than

\* Concerning the several Methods of measuring the Height of the *Clouds*, see my *Young Trigonometer's Guide*, Vol. I. Part II. Chap. II.



Air, must of Necessity fall through it in the Form we call *Rain*.

*A.* But why does it fall in Drops, and not in whole Quantities, as it becomes condensed in the Air?

*B.* So it would fall in great Quantities, were it not for the Resistance of the Air; but the Substance of the Air breaketh and divideth it into Parts, smaller and smaller, the farther it passeth through it, till at last it arrives to us in very small Drops \*.

*A.* Is not *Dew* a Kind of *Rain*?

*B.* Yes; only with this Difference, that whereas *Rain* falls at any Time, and in great Drops, *Dew* falls only at stated Times, and in such very small and fine Drops, that they are scarcely visible, till they are fallen and condensed into Drops on the Tops of Grass, Boughs, &c.

*A.* In the next Place, pray, *Sir*, explain how the *Meteor*, we call *Snow*, is produced.

*B.* *Snow* is produced thus: When the *Vapours* are become considerably condensed, yet not so far as to become liquefied, or dissolved into Water, then, by a special Degree of Coldness in the upper Air, the Particles of the condensed *Vapours* are compelled into a hard, rigid, and glacy Substance, several of which adhering together, form little Fleeces of a white Substance, somewhat heavier than the Air; and therefore descend in a slow and gentle Manner through it, being subject, by its Lightness, to all the various Motions of the Air and Wind; and is what, when arrived to us, we call *Snow*.

\* See Note \* in Page 197.

*A.* And,

*Of Hail, Frost, Ice, and Thawing.* 201

*A.* And, pray, is not *Hail* formed after somewhat a like Manner?

*B.* *Hail* is thus generated: When the *Cloud* which raineth is very high in the Air, or when all the Regions of the Air are very cold, the falling Drops of Water are congealed thereby, and grow into a glacy Substance, somewhat white and hard, of different Size and Figure, according to the Particles of Water, the Degrees of Heat and Cold, the Wind, &c. and this, when come to us, we call *Hail*.

*A.* Although, I suppose, you do not reckon *Frost* and *Ice* among *Meteors*, yet I believe this may be as proper a Place to discourse of them as any; and therefore, if you please, be so good as to explain to me their Natures?

*B.* Dr. *Cheyne* saith, that *Cold* and *Freezing* seems to proceed from a saline or salt Substance floating in the Air, whose Particles are very sharp and pointed, and these insinuating themselves (in a wedge-like Manner) into the Pores of the Particles of Water, do thereby fix, crystallize, and make hard the superficial Parts of Water, and all humid Substances; and hence the incruſted Surface of Earth, Dews, &c. we call *Frost*, and the fixed and crystallized Superficies of Water, we call *Ice*: But, when the Heat of the Sun dissolves those freezing, saline Particles into a Fluid, the Surface of the Water, &c. all return to their former natural State; and this we call *Thawing*.

*A.* Have you any Thing farther to consider, as watery *Meteors*?

*B.* No,

*B.* No, those now described are the whole Tribe; and as we have already largely scanned the Nature of the Wind, which some (as I told you) improperly make a second Sort of *Meteors*, let us now pass to the Speculation of those which are called fiery *Meteors*.

*A.* With a very good Will, *Sir*; nothing delights me so much as those Kinds of natural Researches; and in the first Place, pray which do you count the principal of all the fiery *Meteors*.

*B.* *Lightning*, which is thus occasioned: The Air doth abound with Steams and Exhalations of *Sulphur*, *Bitumen*, *Nitre*, and Salts of various Sorts, *Acids* and *Alkalies*; these being raised by the Sun's Heat into the higher Regions of Air, are there dispersed and ventilated to and fro by the Winds; this Agitation produces a Mixture, and, consequently, a Fermentation of those combustible Sulphurs with the nitrous Acids, which is often to that degree, as to kindle into Flame, and thereby cause those shining Flashes of *Lightning* we see darting from the Sky \*.

*A.* But, pray, *Sir*, what makes the *Thunder* with it?

*B.* *Thunder* is occasioned by the kindling those bituminous and sulphureous Exhalations

\* Concerning the Nature of *Bitumen*, *Sulphur*, *Nitre*, *Acids*, *Alkalies*, &c. see Part IV. Chap. II. and the Notes thereto annexed.

As *Sulphur* is the most inflammable, and *Nitre* the most apt for a violent and sudden *Explosion*, of all Kinds of Matter; so these two Substances are most reasonably thought to afford the *Effluvia*, which compose the Mixture producing *Lightning* and *Thunder*; as they are the two principal Ingredients in *Gunpowder*.



in the Air, by the nitrous Salts, in the same Manner as the Explosion is produced by setting Fire to *Gunpowder*, or *Aurum Fulminans*; and the Reason why we do not hear the dreadful Noise of *Thunder*, so soon as we see the *Inflammation* or *Lightning*, is because Sound is longer arriving to our Ears, than Light to our Eyes; as I have before told you.

A. I have heard talk of *Thunder-Bolts*, and their strange Effects; pray what do Philosophers say of them?

B. What is called a *Thunder-Bolt*, is nothing but a more solid and most rapid Flame, which, with incredible Celerity, flies from the *Clouds* to the Earth, and thro' every Thing standing in the Way, being interrupted by nothing. The more remarkable *Phænomena* of which are as follow: 1. That it affects high Places chiefly, as Mountains, Towers, Trees, &c. 2. That it will sometimes burn a Person's Clothes, while his Body remains unhurt. 3. That, on the contrary, it will sometimes break a Man's Bones, while his Clothes and Flesh receive no harm. And, 4. In like Manner it will sometimes melt or break the Blade of a Sword in the Scabbard, while the Scabbard remains untouched; and, on the contrary, will sometimes burn the Sheath, and not affect the Sword. The Reason of these strange and contrary Effects, Philosophers can but conjecture at, imputing it to the different Figure and Quality of the Particles of \* *Lightning*,

\* There is a Sort of Stone, or Mineral, which the common People call a *Thunder-Bolt*, and imagine it falls from the Clouds in

ning, which renders them capable of dissolving some substances, at the same Time, that they will not touch others.

*A.* All this is very strange indeed; pray what other fiery *Meteors* are remarkable?

*B.* The same aerial Fire, or sulphureous Inflammation, hath different Names, according to the Variety of Figures and Sizes it appears under: As, 1. *Lampas*, a Lamp, when it burneth by little and little, on one Part only. 2. *Bolis*, a Dart, when the Exhalation appears kindled in a long Tract together. 3. *Trabes*, Beams, when the Inflammations appear in the same Place continually. 4. *Chasina*, a Chasm, when the Flame shines or glitters from the Breaks of dividing and splitting *Clouds*. 5. *Ignis Fatuus*, *i. e.* the foolish Fire, or Jack in a Lanthorn, when a fat unctuous Vapour is kindled, and wafted about by the Motions of the Air, near the Surface of the Earth, like a Light in a Lanthorn. 6. *Ignis Pyramidalis*, the pyramidal Fire, when it resembles a Pillar of Fire, standing upright. 7. *Draco Volans*, a flying Dragon, when the middle Parts be thicker and broader than the Ends. 8. *Capra Saltans*, a skipping Goat, when it appears to have a skipping Motion, and to be sometimes kindled, and

in a Stroke of Thunder, and thereby does many times great Mischief, but this is a vulgar Error; the Stone seems, from the Make and Fashion thereof, to resemble more an *artificial* than a natural Production; and being most frequently found where Sepulchres have been, inclines some to think they are some Remains of Antiquity, and were formerly of use in War, and *Arms*, which it was customary with the Ancients to bury with their Ashes. See the Authors mentioned in *Rowning's* Comp. System, Page 146 of Part II. and *Phil. Trans.* N<sup>o</sup> 313, 316, 319, 331, 336.

sometimes not. 9. *Stellæ cadentis*, falling Stars; when the more subtile Parts are burnt away, they fall by the Weight of their viscous and earthy Matter remaining. And these are all the remarkable fiery *Meteors* \*.

\* Of these *Meteors*, the *Ignis Fatuus* is the most frequent and considerable; of which Sir *Isaac Newton* thus writes, "The *Ignis Fatuus* is a Vapour shining without Heat; and is there not the same Difference between this Vapour and Flame, as between rotten Wood shining without Heat, and burning Coals of Fire?" *Optics*, Quest. 10.

The *Meteors* here mentioned are most of them but Parts of the wonderful *Phænomenon* called the *Aurora Borealis*, or Northern Lights, which is an Appearance of streaming Light, darting from a dark Part of the Air which looks like a Cloud; which Streams or Streaks of Light, if low, are perpendicular to the Horizon, and higher, seem to meet in a Center near the *Zenith*; where they have various glancing, quivering and curling Motions; and when the *nitro-sulphureous* Matter, of which it consists, is all spent and burnt away, the *Aurora* commonly degenerates into a bright Twilight in the North, and there gradually dies away. See a large Account of this *Phænomenon* in all its Shapes in *Rowning's* Comp. System, Part II. Dissert. 7. *Monf. Mairan's* Phys. and Hist. Treatise thereof, in the *Memoires de l'Academie Royale des Sciences*; or an Abstract thereof in *Philos. Transf.* N° 431. See an Account of several *Aurora's* in the *Philos. Transf.* N° 320, 347, 348. 351, 352. That wonderful Meteor, *March* 19th, *A. D.* 1719, N° 360. Another the same Year, N° 363. Dr. *Halley* has made it appear from Observations on the Meteor seen on the 31st of *July*, between 9 and 10 at Night, *A. D.* 1708, that these *Meteors* are in the very upmost Part of the Atmosphere, or between 40 and 50 Miles perpendicular Height. Also that *March* 19, *A. D.* 1719, was found by Calculation to be no less than  $73\frac{1}{2}$  *English* Miles perpendicular Height. For a more ample Account of *Meteors*, the Reader may consult the Authors referred to in Note \* in Page 187. Note \* in Page 194, and *Phil. Transf.*



## C H A P. IV.

PHANTASMATOGRAPHY, or a *Philosophical Account of the celestial Appearances*, viz. the RAINBOW, HALO's, PARHELIUMS, PARASELENE's, &c.

A. PRAY, Sir, why do you choose to use such a long hard Word as *Phantasmatography*? I can hardly speak it.

B. Because that best expresses my present Design, which is to let you understand what the Opinions and Discoveries of the best Philosophers are concerning the celestial *Appearances*, as the *Rainbow*, &c. this Word being composed of *φαντάσματα*, *Phantoms*, or *Appearances*, and *γραφῆ*, a *Description*.

A. But, Sir, by your Leave I would ask whether it be not an Innovation to call those Things by the names of *Phantoms*, *Appearances*, or *Apparitions*, which (as yourself says) are by the greatest Philosophers ranked with, and deemed *Meteors*?

B. Be it an Innovation, or what it will, I always choose to call Things by such Names as express what they be, not what they be not; it is certain those Things we discourse of exist no way but in Appearance.

A. What, I pray you, is there nothing of Reality in these Things, as in the *Rainbow* for Instance, but a Form of different Colours?

B. Nothing more indeed; they all owe their Existence to one common Cause, viz. the *Reflection* and *Refraction of Light*.

A. Please

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To front Page 207.

Plate XVII.

Fig: XXVII  
Page 207.

Rain-Bow

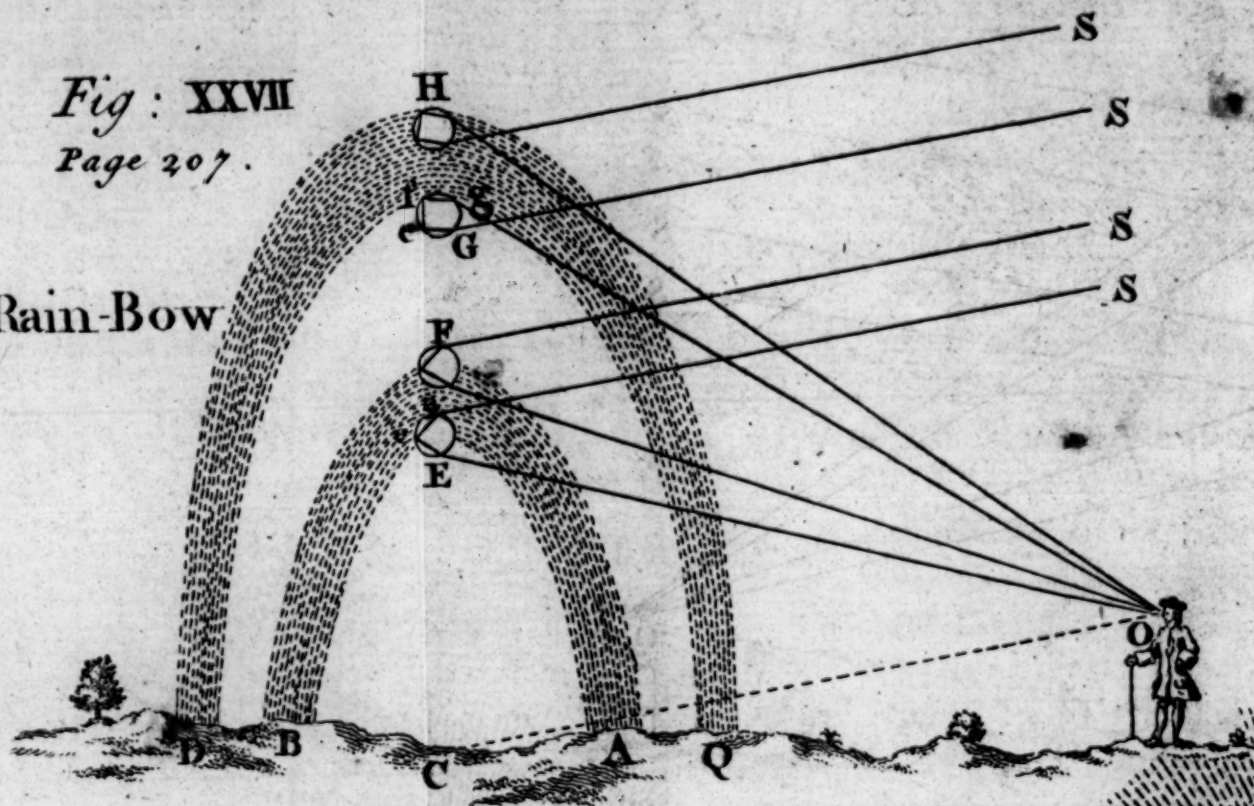


Fig: XXIX  
Page 216.

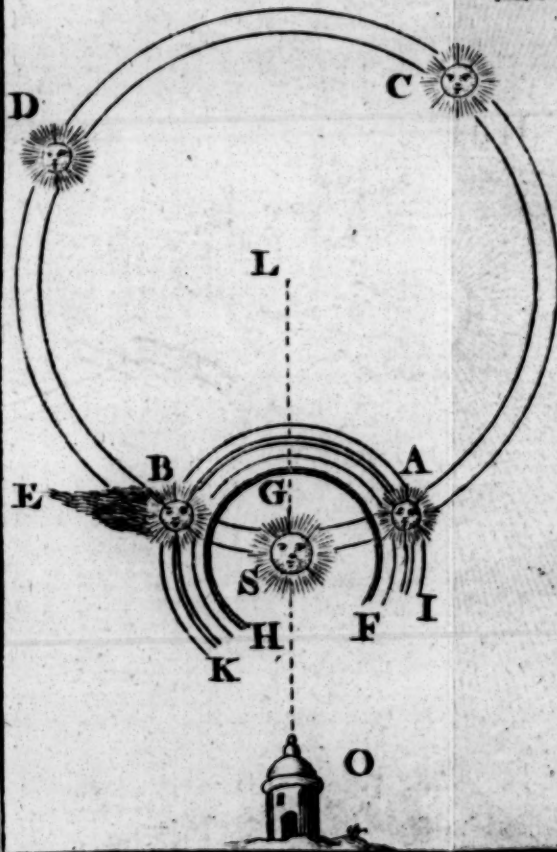
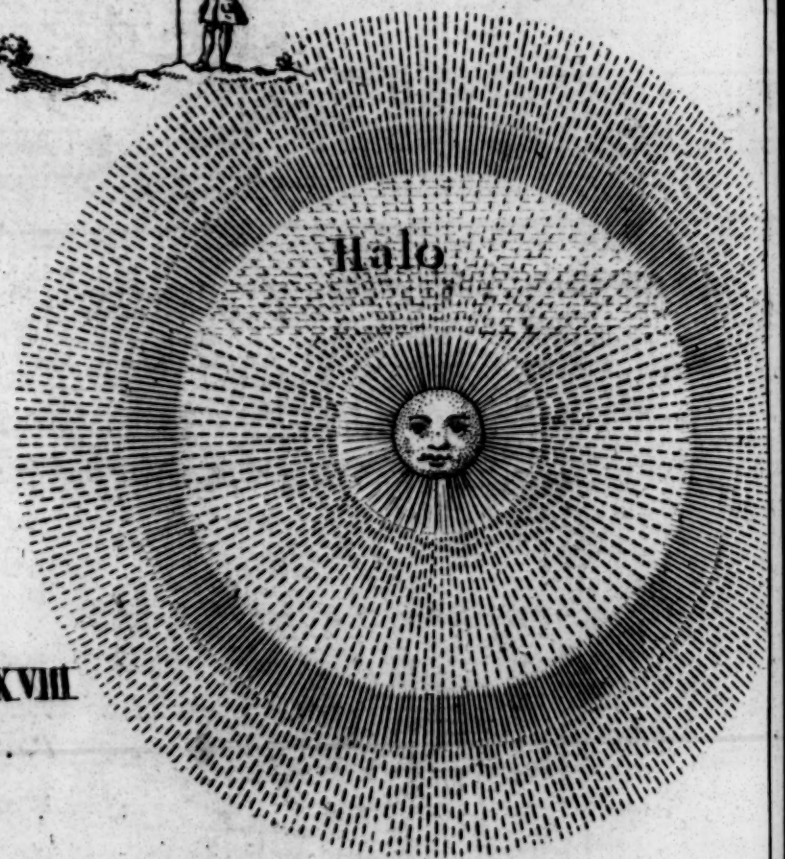


Fig: XXVIII  
Page 215.





*Of the Rainbow, how caused; its Colours.* 207

A. Please to explain a little more particularly the Manner how these *Phænomena* are produced; and, first, how the *Rainbow* acquires its beauteous and wonderful Form.

B. The *Rainbow* is one of the most surprising of all the Works of God (which the *Hebrews* call קשת אלהים the *Bow of God*, and the *Greeks* ταινία, i. e. the *Daughter of Wonder*.) This *Phænomenon* is seen in the falling *Rain*, or *Dew*, and not in the *Cloud* whence that *Rain*, or *Dew*, proceeds; it is caused by a *Reflection* and *Refraction* of the Sun's Rays from the globular Particles of *Rain*: There are often two *Bows* to be seen at the same Time, the interior, as AFB, which is more strong and vivid; the exterior *Bow*, as QHD, which is more faint and weak; the interior *Bow* is formed by two *Refractions* of the Rays of Light, and one *Reflection* of them in the Drops of Water. See Fig. XXVII. on Plate XVII, fronting p. 207.

A. Pray, Sir, exemplify this Matter.

B. I will. In the interior *Bow* (Fig. XXVII. of the Plate as above) let EF be two Drops of the falling *Rain*, and let Sa be a Ray of Light, falling on the Drop E in *a*, from whence it is refracted first to *e*, thence it is reflected to E, whence it is a second Time refracted to the Eye, suppose at O: In like Manner, the same Thing happens in the upper Part of this *Bow*, in the Drop F.

A. Well, and what are we to learn from all this?

B. Hence you easily understand the Reason of the Colours of the *Bow*, if you have not forgot

got what I delivered to you when we were discoursing of Light and Colours : For here you see the Angle  $\text{COE} = 40^{\circ} 2'$  shall be the greatest Angle, in which the most refrangible Rays can after one Reflection be refracted to the Eye; and therefore all the Drops, in the Line OE, shall send the most refrangible Rays most copiously to the Eye, and thereby strike the Senses with the deepest violet Colour in that Region: In like Manner, the Angle  $\text{COF} = 42^{\circ} 17'$  shall be the greatest, in which the least refrangible Rays can after one Reflection be refracted to the Eye; and therefore all those least refrangible Rays shall come most copiously to the Eye in the Line OF, and strike the Senses with the deepest Red in that Region. Do you understand me, pray?

*A.* Yes, *Sir*, very well; and I also understand, that by Reason of the intermediate Degrees of Refrangibility of Rays coming from the Drops between E and F, the Space between E and F shall be painted with proper intermediated Colours; and therefore the whole Face of the *Bow* will be tinged with all the primogenial Colours in their natural Order, *viz*, *Violet, Indigo, Blue, Green, Yellow, Orange, and Red*, from E proceeding to F.

*B.* I am glad to see you so very happily understand the Matter; you will with the greatest Ease and Pleasure understand the *Phænomena* of the upper, or exterior *Bow* QHID, which in short are thus produced: Let G and H be two Drops in the extreme Parts of the upper *Bow*; now let SG be a Ray falling on the Drop in G, whence it is first refracted to *e*, from thence it is first reflected

reflected to F, from F it is a second Time reflected to g, and from g it is a second Time refracted to the Eye at O: Now the same is to be understood in the upper Drop H; hence the Angle COg =  $50^{\circ} 42'$  is the least Angle, in which the least refrangible Rays can after two Reflections be refracted to the Eye; and therefore the Drops in the Line Og shall strike the Eye with the deepest Red, and the Angle COH =  $54^{\circ} 22'$  shall be the least Angle, in which the most refrangible Rays after two Reflections can emerge out of Drops; and therefore those Rays shall come most copiously from the Drops in the Line OH, and shall strike the Sense with the deepest Violet in that Region: And by the same Reasoning the Drops between GH shall strike the Senses with the intermediate Colours; and so the Colours, in the whole Width of the upper Bow, shall lie in this Order from G to H, viz. Red, Orange, Yellow, Green, Blue, Indigo, Violet; contrary to the Order of those in the lower Bow.

A. Sir, I readily perceive the Reason of those Colours in both the Bows, according to the Laws of Refraction you heretofore mentioned; but, pray, why are the Colours of the exterior Bow so much fainter than those of the interior one?

B. Because the Light is twice reflected in the Drops of the exterior, and but once in those of the interior Bow, the Light becoming fainter by every Reflection.

A. I think, Sir, the Rainbow always appears perfectly round; doth it not?

B. Yes; accurately so; for the Lines OE, OF, OG, and OH, turned round their common Axis

O

OC,



OC, shall with their Ends EFGH describe the circular Borders, or Extremities, of the two *Bows*.

*A.* And do they always appear equally large?

*B.* Yes; all *Rainbows* are of the same Dimensions; because no *Bow* can appear but under the Angles of the same Quantities, as before mentioned.

*A.* But we do not always see an equal Quantity of a *Bow*, as I have often observed.

*B.* No, that is impossible you should; for the Sun must be in the Horizon for you to see half the *Bow*, which is the most that can ever be seen; for then the Center of the *Bows* C is on the Superficies of the Earth; but the higher the Sun riseth above the Horizon, the lower the Center C sinketh beneath the Earth's Surface; and consequently the less still you can see of the *Bow*, till, at last, you can see none at all.

*A.* Pray how high must the Sun be for the *Rainbow* not to be seen at all?

*B.* When the Altitude of the Sun becomes equal to the Quantities of the aforesaid Angles, under which the *Bow* appears, they cannot then be seen; that is, when the Sun's Height is equal to the Angle COE =  $40^{\circ} 2'$ , the inner Part E, of the interior *Bow*, descends the Horizon; when it is equal to the Angle COF =  $42^{\circ} 17'$ , the upper Part F, and so the whole interior *Bow* will entirely vanish and disappear beneath the Horizon. Thus, when his Height is equal to the Angle COH =  $54^{\circ} 22'$ , the whole exterior *Bow* will be depressed below the Horizon, and then no Part of any *Bow* at all can be seen; hence all the

*Of various Affections of the Rainbow.* 211

the *Winter* half Year both the *Bows* may be seen all the Day, the meridian Height of the Sun then at greatest being never above  $38^{\circ} 30'$ .

A. What else, pray, is remarkable of the *Rainbow*?

B. The Dimensions in *English* Yards and Miles, I have calculated for every Part of both *Bows*, and are such as are here set down at a given Distance of the Spectator, and Height of the Sun\*.

Also

\* Suppose (as in *Fig. LX. on Plate XIV, fronting p. 179*) a Spectator at O beholds the Bows AEB and CGD at the Distance  $OQ = \frac{3}{4}$  of a Mile, or 1320 Yards; and that the Height of the Sun be at that Time 16 Degrees: In such a Case, I have determined the Dimensions of the Bows as follow.

1. The Center of the Bows P will be depressed below the Surface of the Earth 364 Yards = QP.

2. The lesser Semidiameter of the interior Bow PE will be 1066 Yards; and the greater Semidiameter PF will be 1154 Yards; therefore,

3. The Breadth of the interior Bow EF will be 88 Yards, or 264 Feet.

4. Again, the lesser Semidiameter of the exterior Bow PG will be  $1550\frac{2}{3}$  Yards; and the greater PH, 1770 Yards; therefore,

5. The Breadth of the exterior Bow GH will be  $219\frac{7}{10}$  Yards, or 659 Feet;

6. Consequently, the Breadth of the exterior exceeds the Breadth of the interior Bow by 395 Feet; which shews it to be more than twice the Width of the latter.

7. The Distance of the Summit F of the interior Bow from the Earth Q is 790 Yards; and the Summit of the exterior Bow H from Q is 1406 Yards.

8. The Distance between the two Bows from F to G is  $396\frac{2}{3}$  Yards.

9. The Distance of the Legs AB of the interior Bow on the Earth's Surface is 2052 Yards; that is, one Mile and 292 Yards.

10. The Distance CD of the Legs of the exterior Bow is 3014 Yards; that is, one Mile, and  $\frac{7}{10}$  of another.

11. The Diameter of the interior Bow being 2132 Yards, the Circumference thereof will be  $669\frac{1}{2}$  Yards, or  $3\frac{1}{10}$  Miles, on the Inside.

12. The visible Segment AEB above the Earth, will be above 270 Yards; or one Mile and a half, and somewhat more.

O 2

13. The

Also you have here learned the following Particulars: 1. That two *Bows* do appear together. 2. The Manner how they are both formed. 3. The Reason of the Diversity of their Colours. 4. The Reason why the Colours of each *Bow* lie in an inverse Order to each other. 5. That the *Rainbows* never appear but when it rains. 6. That the *Bow* is in the falling Rain, and not in the Cloud. 7. That it always appears in that Part of the Heavens opposite to the Sun. 8. The Reason why one *Bow* is so much more strong, apparent, and vivid, than the other exterior one. 9. Why they are all in themselves of an equal Bigness. 10. Why we see at some Times a greater, and sometimes a lesser Part of them. 11. Why we can never see above half a *Bow* at most, and when we can see none at all. 12. That the Dimensions of a *Rainbow* may be computed in any known Measure.

*A.* Indeed these are all exceeding curious Circumstances, and far more than ever I under-

13. The inner Circumference of the exterior *Bow* will be  $9535 \frac{2}{10}$  Yards, or a little more than  $5 \frac{1}{10}$  Miles; and the Part CGD above the Earth about  $2 \frac{3}{10}$  Miles.

These are the principal Dimensions of such a *Bow*, which may give the Reader a general Idea thereof, and many Times is very near the Truth. I have shewed the Method of Calculation in my *Young Trig. Guide*, Vol. I. Part 2. Chap. 2. But, by the Mistake of a Number, the Measures there given are erroneous; this Oversight I discovered not till it was too late to correct it.

They who would see the Mathematical Theory of the *Rainbow*, may consult Sir *Isaac Newton's Optics*, Book I. Part 2. Prop. 9. or Dr. *Clark's Notes on Robault's Physics*, Part III. Chap. 17. Also in Dr. *Green's Principles of Philosophy*; and Dr. *Halley's Discourse* thereon, in *Philos. Transf.* N<sup>o</sup> 267. See also N<sup>o</sup> 375. Dr. *Pemberton's View*, Page 394. *Gravesand's Elem.* Book III. Chap. 21. *Chambers's Diction.* and *Harris's Lex. Tech.* under the Word *Rainbow*.

stood



flood before: But you have said nothing of the *Rainbows* which appear by Night in the *Moonshine*; what think you of them, *Sir*?

B. They are in all Respects the same as those occasioned by the *Sunshine* in the Day \*.

A. But, if you assign such a natural Cause for the Production of the *Rainbow*, would not there have appeared a *Bow* in all Ages and Places?

B. Yes, always since there have been Clouds, and Persons to see the Reflection of the Sun's Light from the Particles of falling Rain.

A. Why, there have been Clouds ever since the Creation, have there not?

B. Yes, undoubtedly, and Rain too.

A. Pray, then, how could the *Rainbow* be any Thing of a *miraculous Production*, or be made the Sign of a new Covenant, which God made

\* There are observed four Sorts of *Iris's* or coloured Bows. (1.) The *Rainbow*; of which already; and, for Distinction, may be called the *Solar Bow*. (2.) The *Lunar Bow*; of which see a remarkable Account in *Philos. Transf.* N<sup>o</sup> 331. (3.) The *Marine-Bow*; this appears at Sea in the Water which the Wind carries off the Tops of the Waves; the Colours in this are not so lively as in the *Common-Bow*; the most vivid are a Yellow next the Sun, and a Green next the Sea. They appear in great Number, so that 20 or 30 of them may be seen together. Lastly, they have a Position contrary to that of the common *Rainbow*; that is, they have their curve Part turned towards the Sea, and the Legs upwards. See *Philos. Transf.* N<sup>o</sup> 337, and 369. (4) The *Terrestrial Bow*: for so I call it, as being seen on the Ground; it is caused by Refraction of the Sun's Rays in Drops of Dew on the Grass: Mr. *Langwith* tells us, in one he saw, the Colours were very near as strong as those of the common or *Solar-Bow*. It continually changed its Place with the Beholder. The convex Part was next the Eye, and the *Vertex* was very near him. The Colours took up less Space, and those were more lively, that were nearest him. According to the different Height of the Sun, the Figure of this Bow may be either an *Hyperbola*, *Parabola*, or *Ellipsis*. See *Philos. Transf.* N<sup>o</sup> 369.

with *Noah* and the *New World*, as related *Gen. ix. 13, 14, 15?*

*B.* That Passage does not necessarily imply that it was any *miraculous Production*, or that it did not exist before; for *memorial Signs* or *Tokens* are *arbitrary Things*, and God might as well choose the *Rainbow* for that Purpose, as any *Novelty* whatsoever \*.

*A.* How do you account for those *Phœnomena* we call *Halo's*?

*B.* They are Circles somewhat akin to the *Rainbow*, which appear about the *Sun* and *Moon*, and sometimes variously coloured.

*A.* Pray what are the most remarkable Particulars in the *Halo's*?

*B.* The following: 1. They have always the *Sun* or *Moon* for their Center. 2. They never

\* In *Gen. ix. 13.* our Translation hath it — *I do set my Bow in the Cloud*, which indeed makes it seem as if it were not there before; but if we attend to the Original, we shall find the Word נָתַתִּי to signify, not — *I do set*, but, *I do give*, or *appoint*, or *appropriate* my Bow in the Cloud, for a Sign, &c. Again, the Expression קָשָׁתִי, *my Bow*, plainly implies the Bow was then in being, and was a common and well known Thing. Once more, the Word וְהָיָה, which we render, *and it shall be*, may be as well rendered — *that it may be*, &c. the Prefix וְ being often found to have the Signification of the Adverb *ut*, that. Wherefore the Verses may be truly thus translated; *I do give or appoint my Bow, which is in the Cloud, that it may be for a Sign or Token of a Covenant between me and the Earth; and it shall come to pass, when I bring a Cloud over the Earth, (וְנִרְאָתָהּ) and the Bow shall be seen in the Cloud, (וְזָכַרְתִּי) that I will remember my Covenant that is between me and you, &c.* Thus, by giving the Particle וְ its due Acceptation in three several Places, the three Verses run very natural, and imply no new Wonder or Miracle. I hope those Gentlemen who have been so ready in charging me with casting Contempt on the Scriptures, will believe me, if I tell them once more, that I esteem the Bible above all Books in regard of Religion, and that what I say reflects only on the *Superstition* or *Ignorance* of those who would make the Scriptures say any thing inconsistent with *Reason*, *Common-sense*, or the *Nature of Things*.

appear

appear in a rainy Sky, but in a rimy and frosty one. 3. They appear blue on the exterior Limb, or Border, and red on the interior. 4. The Air contained within them is more obscure than the ambient Air without round about them. 5. The Limb of a *Halo*, or Width of its Circle, is about half a Degree, or 30 Minutes. 6. The Diameter of the whole Circle of the *Halo*, is about 44 or 46 Degrees, more or less. See *Fig. XXVIII.* on *Plate XVII*, fronting *p. 207*.

*A.* And, pray, is the *Halo* formed in the same Manner as the *Rainbow*?

*B.* The *Halo* is formed by the Refraction of the Rays of Light, without any Reflection, as in the *Rainbow*; and this Refraction of the Light in the Hailstones in the Air, will be strongest at about  $22^{\circ}$ , or  $22^{\circ} 30'$ , distant each Way from the Sun or Moon, and gradually decay both Ways as the Distance increases or decreases; and consequently at that Distance there will be formed a Circle, we call the *Halo*, about the Sun or Moon, which *Halo*, as often as the Hailstones are duly figured, may be coloured; and then it must be red within by the least refrangible Rays, and blue without by the most refrangible ones: And this is the Substance of all we know worth mentioning of the *Halo's*.

*A.* Then a Word next, if you please, concerning the *Parbelia*; pray what are they in a philosophical Sense, and why so called?

*B.* The *Parbelia* are what the Vulgar call *Mock-Suns*, and *Paraselenes* are *Mock-Moons*, which sometimes appear in the Heavens, and are only Representations of the Face of the true Sun



or Moon by Way of Reflection in the Clouds; they are so called, because they appear *παρὰ τὸν ἥλιον*, besides the true Sun, and *παρὰ τὴν σελήνην*, besides the true or real Moon.

*A.* In what Manner do they appear?

*B.* Thus: 1. There is observed a very great white Circle parallel to the Horizon, as ACDB, passing through the true Sun at S. See *Fig. XXIX.* on *Plate XVII.* fronting *Page 207.* 2. In the Parts of this white Circle appear the *Parbelia*: As in 1629, *March 29*, there appeared at *Rome* four Mock-Suns, as ABCD, to a Spectator in the Observatory at O; though not all of them equal, nor equally strong and vivid, nor of equal Duration. 3. They are in Number unequal, being sometimes four, as here, sometimes more or less. 4. They appear sometimes tinged with the Colours of the *Rainbow*, now stronger, now fainter. 5. *Halo's* frequently appear at the same Time; as in the Case now mentioned, there appeared two broken ones, as the interior one FGH, very strong and *Rainbow-like*, and the exterior one, IABK, passing through the two *Parbelia* nearest the Sun AB, but so weak and faint as scarcely to be seen. 6. Among these four *Parbelia*, one, viz. the *Parbelium* B, appeared to have a Tail, Comet-like, extending to E, the Part opposite to the Sun S.

*A.* But, *Sir*, in viewing this Scheme, doth not I represent the Point vertically over the Observatory O, as well as the Center of the great white Circle; and so the Spectator would see the true Sun, the *Halo's*, and the two *Parbelia*,

*belia*, A, B, before him, and the other two, C, D, behind him; would he not?

B. Yes, that is the right Way to conceive a true Notion of the *Phænomenon*.

A. Please to let me know how the Philosophers say they are formed.

B. The great white Circle all round you is formed by the Reflection of the Sun, from those icy Particles floating in the Air of the same Height of the Sun; and therefore the Sun must be in it, as at S: The *Halo's* FH and IK are produced as before said: The *Parbelia* ABCD are produced by two Refractions and one Reflection of the Sun's Rays falling on the icy Particles in certain Parts of the white Circle; whence there is an Image of the Sun not only formed, but painted with the Colours of the Bow: But the Causes of these *Phænomena* are not so obvious as those of the *Rainbow* and *Halo's*, and therefore we leave them \*.

A. But, before we quite dismiss this phantastic Subject, pray give an Hint what that *Phænomenon* may be we call *Virgæ*?

B. This is only an Apparition of the Sun's Rays darting through the Interstices of the Clouds, or otherwise, in the Form of a Bundle of Rods as it were. And now, from those Things which are situated so remote from us,

\* If the Reader be desirous of seeing a larger and more various Account of *Halo's*, *Parbelia*, and other Appearances of this kind, let him peruse Sir Isaac Newton's *Optics*, Book I. Part 2. Prop. 9. Descartes's *Meteora*, in his *Opera Philosoph.* Mr. Hugen's Account of the Causes of them, in *Philos. Trans.* N<sup>o</sup> 60. Also N<sup>o</sup> 22, 129, 13, 47, 102, 250, 251, 262; and all the Authors referred to in Note \*, Page 187.

and

and in a Region altogether inaccessible to Mankind, let us descend to the Contemplation of the manifold Curiosities and Wonders discovered in a Place we know better, and nearer Home; to wit, in the Globe of our Earth.

*A.* With all my Heart, *Sir*; for I cannot say, indeed, but that I am almost weary with travelling so long through all the ethereal Regions of the Universe; yet, as it hath been on the Wings of Contemplation, and I am saturated with the delightful Curiosities of Nature, I am so far from regretting it, that I count it the best and most profitably spent Part of my Time.





THE  
*Philosophical Grammar:*  
Or, VIEW of  
Modern Philosophy.

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PART IV.

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GEOLOGY:

CONTAINING,

- I. A philosophical View of the *terraqueous Globe*.
- II. The Philosophy of *Earths, Stones, Metals, Minerals, &c.*
- III. The Philosophy of *Water*, viz. the *Seas, Rivers, Springs, &c.*
- IV. The Philosophy of *Plants and Vegetation*.
- V. The Philosophy of *animal Bodies*, viz. the *human Body, Brutes, Fowls, Fishes, Insects, Reptiles, Shell Animals, &c.*

Shewing the wonderful Discoveries of the modern Naturalists  
in those Parts of Science.

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CHAP. I.

GEOLOGY, *or the general Doctrine of the Globe; of its various Divisions and Subdivisions; of the Vicissitude of Seasons, and other general Affections.*

A. PRAY, what is imported by the Word  
Geology?

B. A

B. A Discourse of the *Earth* in general, or *Terraqueous Globe*, as consisting of *Land* and *Water*, from the Greek Words γῆ, the *Earth*, and λόγος, a *Discourse*.

A. How is the *Earth* divided?

B. The first great and most general Division of the *Earth* is into *Land* and *Water*; which again are severally subdivided into other lesser Parts.

A. Pray how is the *Land* subdivided?

B. Into the following Parts, *viz.*

1. CONTINENTS, which are great Tracts of Main Land, containing whole Countries and Kingdoms; as *Europe*, *Asia*, *Africa*, and *America*.

2. ISLANDS, or Parts of Land environed by the Sea; as *Britain*, *Japan*, *Madagascar*, &c. \*

3. PENINSULAS, which are Parts of Land encompassed by Water, excepting on one Part, by which they are joined to the main Land, or Continent; as *Morea*, &c.

4. ISTHMUS is that Neck of Land joining the *Peninsula* to the main Land.

5. PROMONTORIES, or *Capes*, are those high Parts of Land which run far out into the Sea in a Point; as the *Cape of Good Hope*, &c.

\* See an Account of a new Island raised out of the Sea near *Saturnini* in the *Archipelago*, May 12, 1707, by Dr. *Sherard*, in *Philos. Transf.* N<sup>o</sup> 314. Also of another new and burning Island raised out of the Sea near *Tercera* on Novemb. 20, 1720, by *Thomas Foster*, Esq; N<sup>o</sup> 372. This Isle is in Lat. 38° 29', and Long. 25° 33'. In N<sup>o</sup> 361, there is an Account of the *Sunk Island*, as it is called, in the *Humber*, which was recovered from the Sea about seventy years ago, and is about nine Miles in Circumference, and has a very fat and fertile Soil.

A. And

A. And, pray, what are the Subdivisions of the Water on the Globe?

B. These following, viz.

1. OCEANS, are those vast Collections of Water which cover some greater Parts of the Earth's Surface; as the *Atlantic Ocean*, *Mare del Zur*, &c.

2. SEAS; those are lesser Assemblages of Water, which lie before, and wash the Coasts of some particular Countries; as the *Ethiopic*, *Indian*, *Arabian*, &c. Seas.

3. GULPHS, are those Parts of the Sea every where environed with Land, except one Passage whereby they communicate with the Sea; as the *Arabian Gulph*, &c.

4. STRAITS, are those narrow Passages of Water which either join a *Gulph* to the neighbouring Sea, or one Part of the Sea or Ocean to another; as the *Straits of Gibraltar*, &c.

5. RIVERS, are Streams of fresh Water arising from some Fountain-head, which by a continued Current arrive and discharge themselves into the Sea\*.

A. What other Divisions do you make on the Surface of the Globe?

B. The Earth is again divided, with respect to the Length of Days and Nights, into *Climates*.

A. What do you call a *Climate*?

B. CLIMATES are such Parts of the Earth's Surface on each Side the Equator, and parallel

\* See an Account of the Rise of several of the most considerable Rivers in *Europe* by J. G. Schinckzer, F. R. S. in *Philos. Trans.* N<sup>o</sup> 406. See also N<sup>o</sup> 119. And *Varen. Geog. gener.* Lib. I. Cap. 16. throughout.

thereto,



thereto, that the artificial Day in one surpasseth that in the other by half an Hour.

*A.* Are there yet any farther Kinds of Divisions of the Earth's Surface?

*B.* Yes, and a very remarkable one too, *viz.* into the ZONES, called the torrid, temperate, and frigid Zones \*.

*A.* Pray what doth the Word *Zone* mean?

*B.* It is derived of the *Greek* *ζώνη*, a *Belt*, or *Girdle*; because they, being large parallel Parts of the Earth's Surface, do encompass the Globe of the Earth, as a *Belt* doth the Body of a Man.

*A.* What is the *torrid Zone*, and why is it so called?

*B.* In the Map adjoined, you may observe a certain Space on the Earth's Surface, over the Middle of which passeth the Equator, and is included between two double Parallels, one towards the *North*, called the Tropic of *Cancer*, and the other *Southward*, called the Tropic of *Capricorn*; over all this Space, from the *North* to the *South*, you may observe the Line called the *Ecliptic*, or the Sun's Path, doth pass; and consequently doth at some Time of the Year or

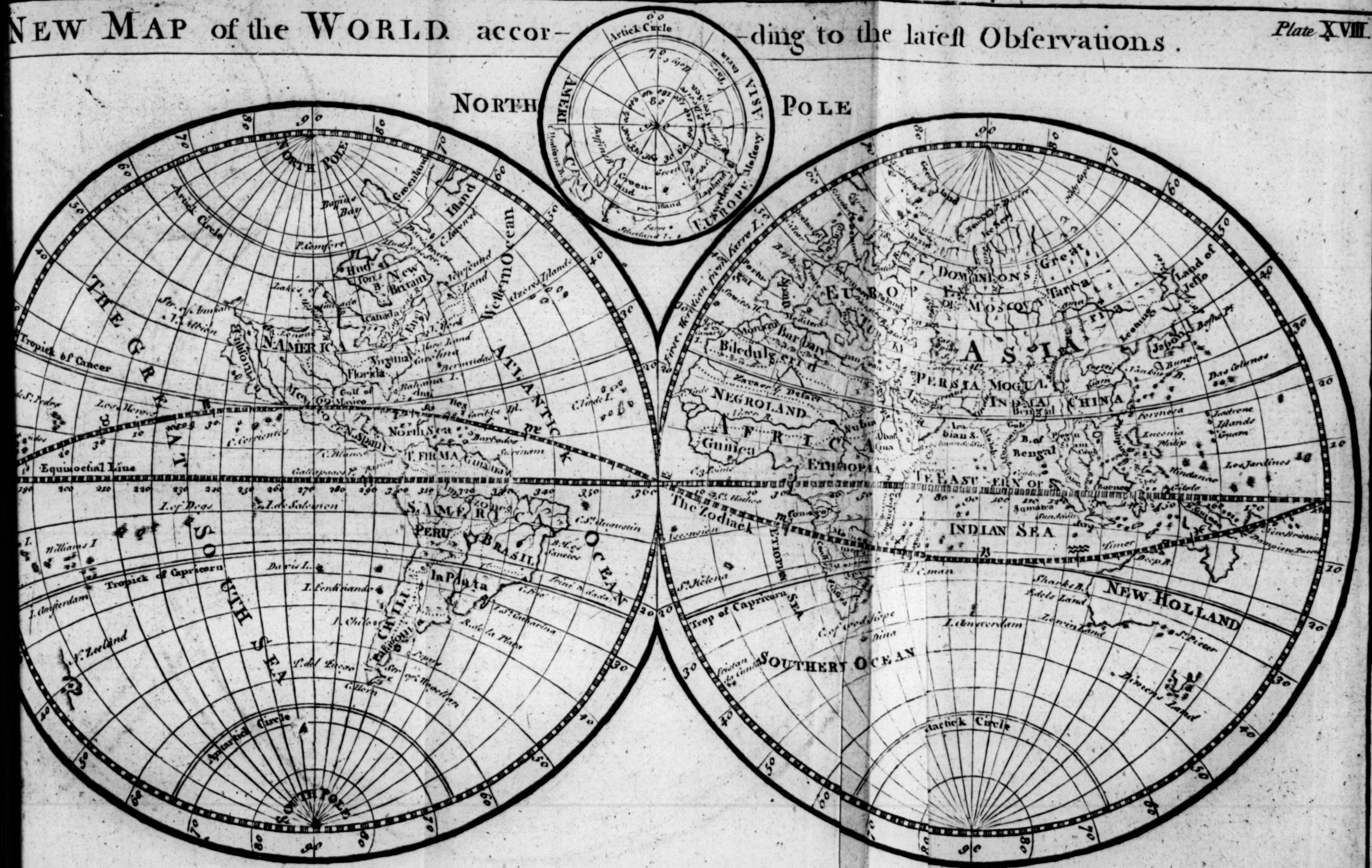
\* *Virgil* and *Ovid* have both given a very beautiful Description of the *Zones*; of which the latter, in *English*, runs thus:

And as two equal Zones on either Side,  
On left and right, the measur'd Heav'ns divide:  
While the fifth rages with intenser Heat;  
So the same Lines the parted Globe compleat:  
Excessive Heats possess the midmost Place,  
A sad; adust, inhabitable Space;  
On two, eternal Hills of Snow are seen,  
And two, indulgent Heav'n has plac'd between,  
Whose Climes a due proportion'd Mixture hold,  
Temper'd with equal Parts of Heat and Cold.



NEW MAP of the WORLD according to the latest Observations.

Plate XVIII



Bowen Sculp.



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other pass twice over every Part thereof, and by its perpendicular Rays doth greatly heat and scorch it; and from its being thus *torrified* by the Sun's excessive Heat, it is called the *torrid Zone*.

*A.* Which do you call the *temperate Zones*?

*B.* These are two Tracts lying next the *torrid Zone*, one on the *North*, the other on the *South*, each bounded by, or contained within, the Tropics and Polar Circles, as are plainly discerned in the Map; they are called temperate, because the Sun never passeth over any Part of them, but shining obliquely on them, maketh them to have always a moderate Degree of Heat and Cold.

*A.* And where do you place the *frigid Zones*?

*B.* They are those two Tracts of the Earth's Surface contained within the Polar Circles, *Northward* and *Southward*, as you see in the Map; over the Center of each of these is the Pole; the Sun being at a great Distance from these, and absent so long from several Parts thereof, together with the great Obliquity of his Rays when present, causeth prodigious Cold continually over all those Parts; and they are therefore called the *frigid Zones*.

*A.* Please to let me understand the Reason of the different Degrees of Heat and Cold, in any one Place, throughout the Year.

*B.* This will be better apprehended, if we first discourse a little of the various Seasons, and their Causes, in which the Differences of *Heat* and *Cold* are found; and first, if you please, we will enquire the Reason of the different Length of Days and Nights.

*A.* That

*A.* That will be very acceptable to me; for I must confess to my Shame, though I have lived so many thousand Days and Nights, I could never yet tell why one was longer or shorter than another; be pleased therefore to make the Matter evident, if possible, by a Scheme.

*B.* Yes, I will warrant it is possible. Cast your Eyes therefore on *Fig. XXXI.* on *Plate XXI,* fronting *Page 234,* and view well the Situation of the Globe; it is there in its proper Position for *London,* which you see in the *Zenith* at *I,* whose *Horizon* is the Line *HO*; all under which to us is dark, and all above it light.

*A.* Very good, so far I can follow you; pray go on.

*B.* Then next you must conceive the great Circle *OPQ* to be the Meridian of *London,* on which the Sun comes every Day at Noon, and every Night at Midnight, on some Part of it or other.

*A.* But, pray, why do you say on some Part or other?

*B.* Because the Sun is never precisely on the Meridian in the same Place two Days together; but every Day declines from, or approaches nearer to, the *Equinoctial Line EQ,* which furrounds the Earth in the Middle.

*A.* Pray how far does the Sun decline from the *Equinoctial* at most?

*B.* The Sun, from *March 11* to *June 11,* declines from *Æ* to *T,* which is  $23^{\circ} 30'$ , or  $1633\frac{1}{2}$  *English Miles* on the Earth's Surface; then, from *June 11* to *Sept. 15,* it returns again from *T* to the *Equinoctial Æ,* from which it passeth to *V,* where

where it is found about *December 10*; and thence returns again to  $\text{Æ}$  by *March 10*.

A. Then I see the Sun is nearest *London* at T, at a mean Distance in  $\text{Æ}$ , and farthest of all from us at V.

B. Yes, it is so: Now observe the Sun in the Meridian at these three several Places, T,  $\text{Æ}$ , V; then, because the Earth turns each Day once round its Axis PD, the Sun in each of those Places will describe a Circle; one of which, viz. the middle one,  $\text{ÆQ}$ , will be the *Equinoctial* itself; and the other two, TR and VW, will be parallel thereto on either Side, and are the Tropics of *Cancer* and *Capricorn*. Do you understand me, Sir?

A. Yes, pretty well; you mean, that the three Lines, TR,  $\text{Æ}$ , VW, represent the Path of the Sun from Noon in T,  $\text{Æ}$ , V, to Midnight in R, Q, W, on *June 10*, *March 10*, and *December 10*, do you not?

B. Yes, you take me very right; now it is obvious, when the Sun has passed half Way from Noon to Midnight, it will be found in the Line PD, (the same here as the Earth's Axis) in the Points G, Y, M, and that then it is Six o'Clock; also, when it touches the Horizon in XYZ, it there setteth from our Sight, and consequently *terminateth* the *Day*, and *beginneth* the *Night*, on these Days.

A. Very well, Sir, I believe I see your Conclusions already.

B. Indeed, Sir, they are very evident: For, I. Suppose the Sun in  $\text{Æ}$  the Equinoctial, then it is apparent, that it will on these Days, viz.

P

*March*



*March* 10, and *Sept.* 12, be in the Horizon Y precisely at Six o'Clock; and therefore his Path by Day  $\text{\AE Y}$ , will be just equal to the same by Night  $\text{Y Q}$ . 2. Suppose the Sun at T, as on *June* 10, then it is at Six o'Clock in G above the Horizon a great Way; but it descends the Horizon at X; and therefore the daily Arch TX is longer than the Arch by Night XR, by the Difference GX. 3. Suppose the Sun in V, then the diurnal Arch VZ is just as long as the nocturnal Arch XR before, and the nocturnal Arch ZW is here the same Length with the diurnal Arch TX, in the foregoing Case. Do you understand me hitherto?

A. Yes, I believe I do: As the Sun declineth from  $\text{\AE}$  to T, and back again, the Length of Days exceeds the Length of Nights, in as much as it must pass some Distance beyond the Six o'Clock Line GY, before it can come to the Horizon; and on the contrary, while it is between  $\text{\AE}$  and V, it meets with the Horizon before it comes on the Six o'Clock YM, and therefore the Days are shorter than the Nights, by just so much as the Nights are shorter than the Days in the other Case: This is what you mean, is it not?

B. Yes, the very same: I have only this to observe, that the farther you go *Northward*, the greater is the Difference or Inequality of Days and Nights; and the contrary.

A. That I also perceive plainly from the Figure; for the nearer HO inclines to  $\text{\AE Q}$ , the greater will be TX, and the lesser VZ, or the greater will be GX, or MZ, the Difference of  
Day

Day and Night: But, pray, what means that obscure Part of the Night, comprehended between HOAB, which is neither dark nor light?

B. It is the *Crepusculum*, or what we call the *Twilight*, the Line AB being 18 Degrees below the Horizon HO, and during the Time the Sun passeth from HO, to AB, in the Parallel of any Day, his Rays are partly refracted by the *Atmosphere*; and so we have some faint Light 'till he gets below the Limit AB, when we are left in total Darkness.

A. I understand you mean, it is *Twilight* while the Sun passeth from X to R, from Y to S, and from Z to M, on the Day the Sun describes the Parallels TR,  $\text{ÆQ}$ , and VW; do you not?

B. Yes, I do; and hence, at *London*, you may observe, that when the Sun is in T, that is, in the Tropic of *Cancer*, there is no dark Night at all; for the Parallel of that Day TR doth not touch AB, nor will it for about a Month before and after; that is, from *May 11*, to *July 10*, there is no dark Night.

A. Pray, when doth the shortest *Twilight* happen in all the Year?

B. On *October 1*, and *February 19*; for then the Sun describes the Parallel, whose Distance is the least, between HO, and AB, of any other whatsoever\*.

A. Well, Sir, I thank you for your Labours to rectify my Notions of *Day*, *Night*, *Twilight*, &c. which, tho' they are common Things, yet,

\* See the Method of investigating the shortest *Twilight* in Dr. *Hill's Astronom. Lect. XX. Page 239.*

I never had a good Notion before now: Nor do I yet well conceive the Reason and Manner of the various *Changes and Vicissitudes of the Seasons* which happen through the Year; and, if you could represent this to me in a Figure, I should be greatly obliged to you.

B. I have contrived a Scheme for that very Purpose (*Fig. XXX. on Plate XIX, fronting p. 228.*) which please only to view very carefully, and you will see therein a natural Representation of a *whole Year*.

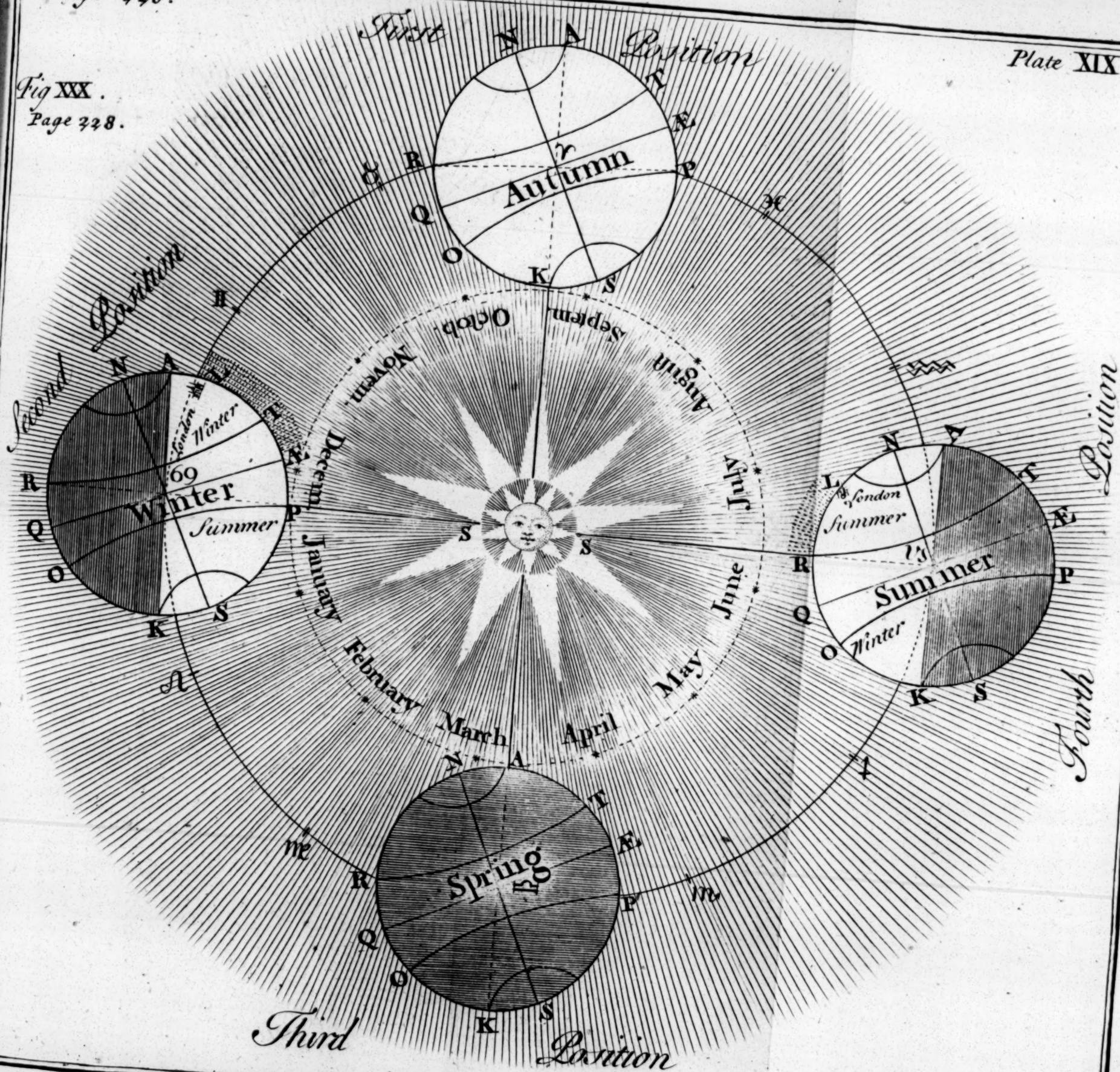
A. Sir, I observe it with all Diligence, and see several Things therein very remarkable: But yet, I beg you would please to point them out in the natural Order, in which they should be considered, that I may the better apprehend the Design of the whole.

B. That I will; and *first*, you observe in the Center of the Scheme is placed the Sun S; about which, at a great Distance, is the circular Orbit of the Earth, called the *Zodiac*, divided into its 12 Signs, *viz.* ♈, ♊, ♉, ♋, ♌, ♍, ♎, ♏, ♐, ♑, ♒, ♓. in which you see the Earth in four several Positions; the *first* in *Aries* ♈; the *second* in *Cancer* ♋; the *third* in *Libra* ♎; the *fourth* in *Capricorn* ♐; within this there is a dotted Circle of *Months*, shewing the *Time of Year* when the Earth is in any Part of her Orbit: Now with regard to the Earth itself, you see its Position every where is somewhat inclined to the Plane of her Orbit; that is, the Earth's *Axis* NS doth not stand perpendicular to the *Plane of her Motion*, or (which is the same) is not parallel to the *Axis* of the said Plane, but maketh an Angle therewith equal to the Angle made by the Intersection of NS



Fig XXX.

Page 228.





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with AK; for this AK you see is always a Diameter of that Circle which boundeth Light and Darknes on the Earth's Surface, and is every where perpendicular to the Plane of the Earth's Motion, or parallel to the Axis of that Plane. Now the Earth's Axis, thus inclined, is every where parallel to itself; that is, the Angles  $N^r A$  in the *first*, and  $N^s A$  in the *second*,  $N^a A$  in the *third*, and  $N^b A$  in the *fourth* Position of the Earth, are all equal to each other, and so are equal in every other Position through its Orb. The Quantity of this Inclination or Obliquity of the Earth's Position is 66 Degrees 30 Minutes, equal to the Angle  $N^r R$ , &c. Now it is evident, that, by Means of this parallel Inclination of the Earth, the *North* and *South* Parts of the Earth, or its Poles N and S, will be sometimes nearer the Sun, sometimes farther off, and sometimes each Pole will be equally distant from the Sun; and from hence we shall see the Reason of, and how the Seasons are all produced. For, 1. In the *first* Position of the Earth in *Aries*  $r$ , about the 12th of *September*, and in the *third* Position in *Libra*, in *March* the 10th, it is evident the Sun doth there enlighten the Earth from Pole to Pole, or the Circle bounding Light and Shadow doth then pass through the Poles, and consequently at equal Distances from the Equator  $\text{AEQ}$  (in which the Sun then appears) the Sun's Heat will be equal on both Sides; and thus an *Equality of Days and Nights*, joined with a mean Proportion of Heat, constitute those *two Seasons* of the Year, we call *Spring* and *Autumn*. 2. Again, in the *fourth* Position



of the Earth in  $\varpi$ , about the 10th of *June*, when the Sun will appear in the opposite Sign *Cancer*  $\varpi$ , it is plain the *North* Pole N, and all the Parts about it to the Distance of A, will be situated nearer towards the Sun than before; and all the *South* Parts removed farther from the perpendicular Rays thereof. The perpendicular Rays of the Sun here fall on R, which is distant from the Equator Q *Northward*  $23^{\circ} 30'$ ; and therefore all Places in *North* Latitude, receiving the Sun's Rays nearer their *Vertex*, or *Zenith*, will find a greater Degree of Heat, and a longer Continuance of his Light by Day, and therefore have now their *Summer*, as at *London*, while all the Inhabitants of *Southern* Latitude have their *Winter*. 3. Lastly, in the *second* Position of the Earth in  $\varpi$ , the Sun will seem in *Capricorn*  $\varpi$ : It is manifest the *North* Parts will here be in Darkness, and have their *Winter*, as they in *South* Latitude had theirs, in the last Position; that is, by being removed farther from the Perpendicularity of the Sun's Rays; and under the Obliquity of the Sun's Rays the Heat is diminished, and also the Duration of his Light by Day; which together must cause *Winter* in all the *Northern* Latitudes. I hope you have understood me through this long Harangue?

A. Indifferently I have; and can easily see from this Scheme the Reason why we must have those Vicissitudes of Seasons, as you have explained it: But I really thought *Summer* had been occasioned by the Sun's being very near  
us,

*Distance of the Sun in Summer and Winter.* 231

us, and the *Winter* by his going farther from us, 'till I saw you assign other Reasons for it.

B. Aye, that is the general Mistake of common People, they think the Sun is really nearer in *Summer*, and farther off in *Winter*; when the truth is just the contrary, for the Sun is much nearer in the *Winter* to our Earth than it is in the *Summer*.

A. This is a *strange Paradox*, indeed; pray how do you make it out?

B. Nothing is more easily proved; for look once more on the Scheme, and heed it well, and you will see the Earth's Orb is not a *Circle*, but an *Oval*, whose longer Diameter is  $\infty$  S  $\frac{1}{2}$ , in which the Sun is; but much nearer  $\infty$ , in which the Earth is at *Winter*, than  $\frac{1}{2}$ , its Place in *Summer*.

A. I understand you very well, Sir; you mean, the Distance SP is less than the Distance SR; which I did not before observe indeed, though I might, for it is obvious enough.

B. It is right, I see you apprehend me well; and therefore you will also understand, that the *Summer* half Year is somewhat longer than the *Winter* half Year; that is, the Part of the Earth's Orb  $\triangle$   $\frac{1}{2}$   $\gamma$  is greater than the other Part  $\infty$   $\triangle$   $\gamma$ , and therefore more Time will be requisite to pass the *Summer* half Year than the *Winter*, by about eight Days; and hence, also, the Sun will seem to move somewhat slower in the *Summer* than in *Winter* \*.

\* For a much larger and clearer Illustration and Representation of these Matters, see my large Print, entitled, SYNOPSIS SCIENTIÆ COELESTIS; OR, *The Knowledge of the HEAVENS and the EARTH displayed.*

*A.* All these Things evidently follow indeed, *Sir*, from the Consideration of the Earth's Orbit being an *Ellipsis*: But I am not fully satisfied about the Sun's Heat being so weak and faint in the *Winter*, when the Sun is really nearest to us; and so very strong and intense, when the Sun is really farther by much from us.

*B.* You will soon see the Reason of that when you consider, 1. That it is not the Rays which fall on us, but those which are reflected back from the Earth's Surface, that chiefly heat us. 2. That those which fall on us most directly, or nearest to the Perpendicular, are the most in Quantity, and act on us with the greatest Force: Thus, in *Fig. XXXII. on Plate XXI*, fronting *Page 234*, the Rays of the Sun, on the longest Day of *Summer*, fall on *London*, under the Angle *TLO*, in *Spring*, or *Autumn*, under the Angle *ÆLO*, and in the Midst of *Winter*, under the Angle *VLO*, and the Quantity of those Angles are respectively  $65^{\circ}$ ,  $38^{\circ} 30'$ ,  $15^{\circ}$ ; wherefore the Force of the Sun's Rays, in each of those Cases, shall be proportioned to the Sines of those Angles, which are, as 88294, 62251, and 25881; that is, 10,  $7\frac{5}{10}$ , 3, nearly, for those Numbers are in Proportion to the Sines *TA*, *ÆB*, and *VC*, of the aforesaid Angles: The Quantity of the Rays also falling on the same Extent of Surface is greater or smaller, as their Obliquity is lesser or greater, and so the Intensity of Heat is greater and smaller; and therefore the Sun's Heat in *Winter* must be weakest, because then the Sun's Rays fall most obliquely on us. Besides, 3. That Rays of the Sun pass through a much greater Part of the  
*Atmo-*



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Fig. LXI.  
Page 223.

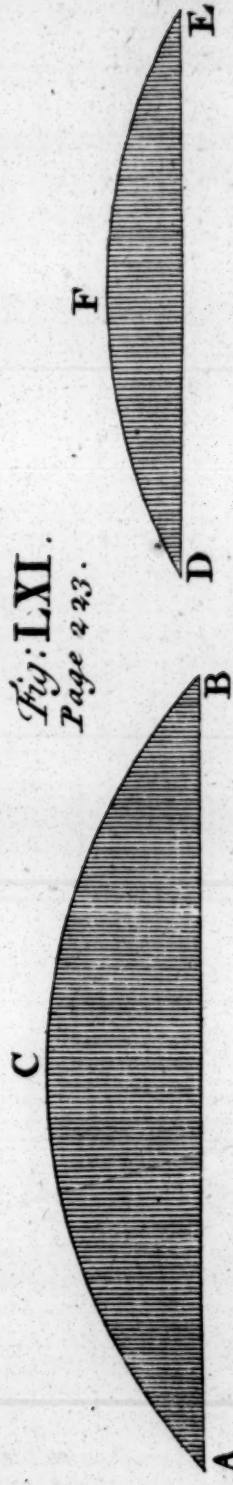


Fig. LXII.  
Page 237.

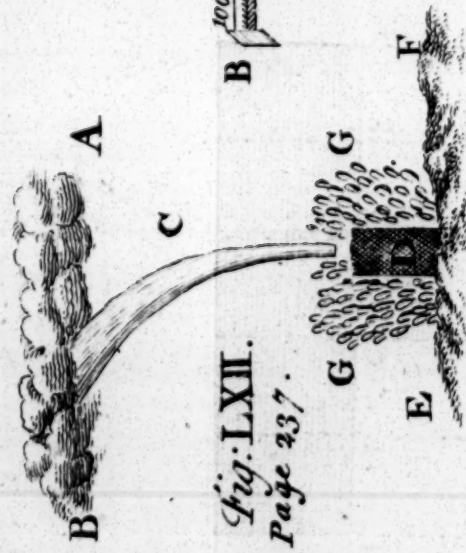


Fig. LXIII.  
Page 263.

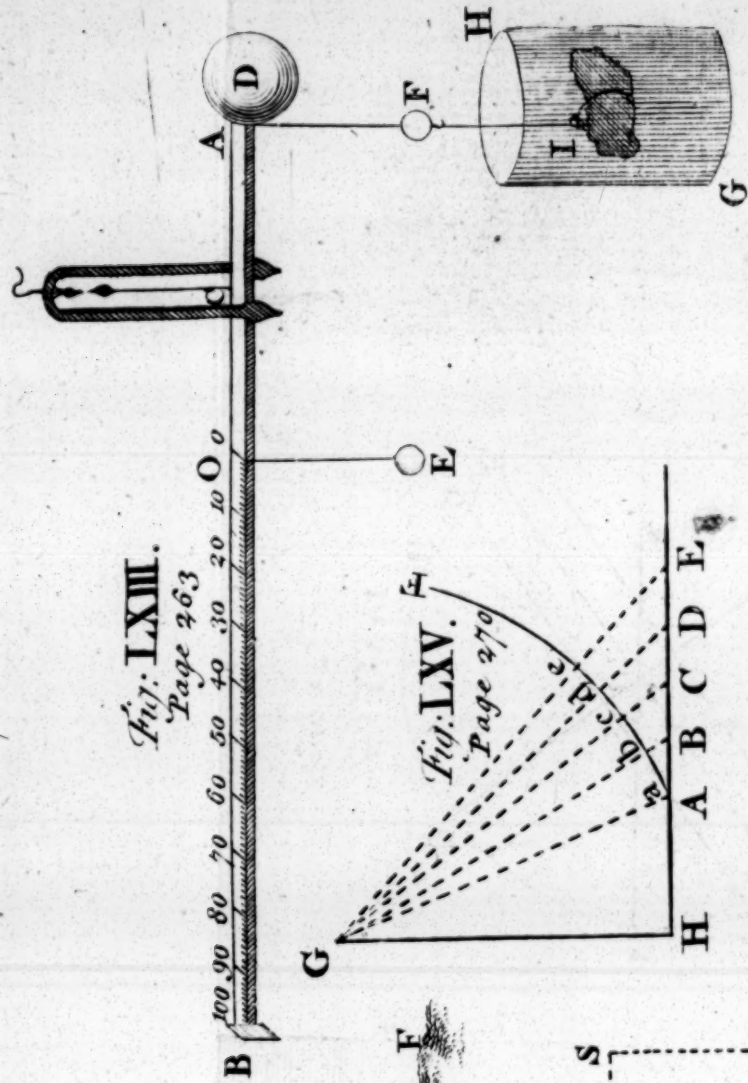


Fig. LXV.  
Page 270.

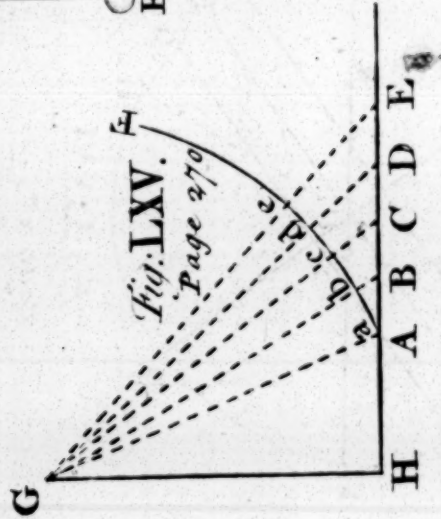


Fig. LXIV.  
Page 270.

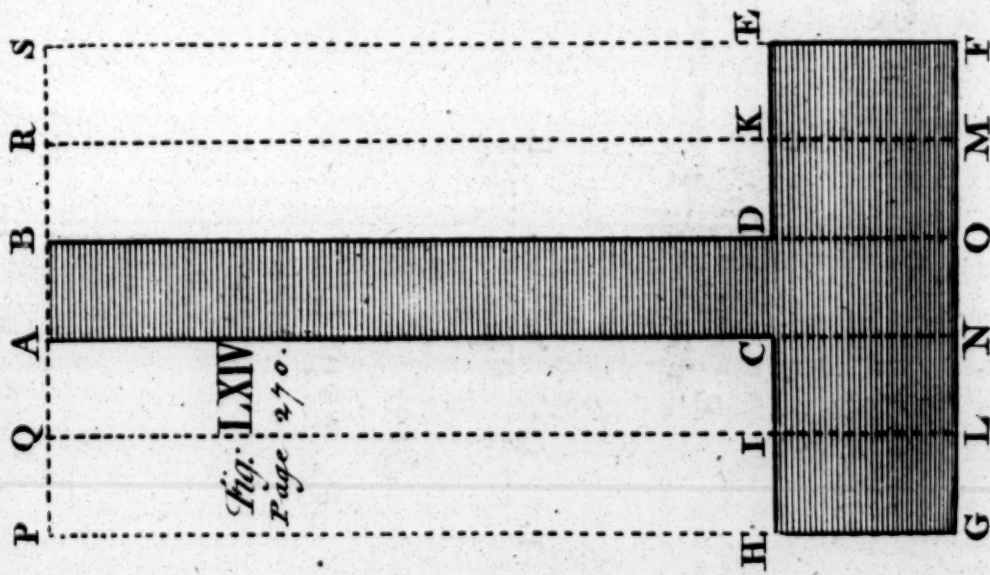


Fig. LXVII.  
Page 295.

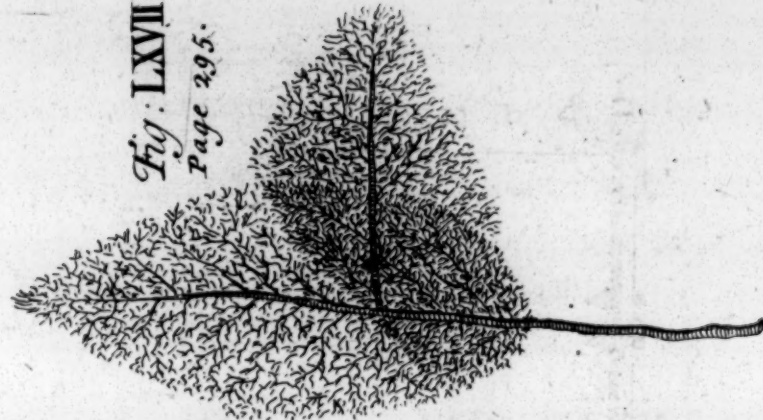
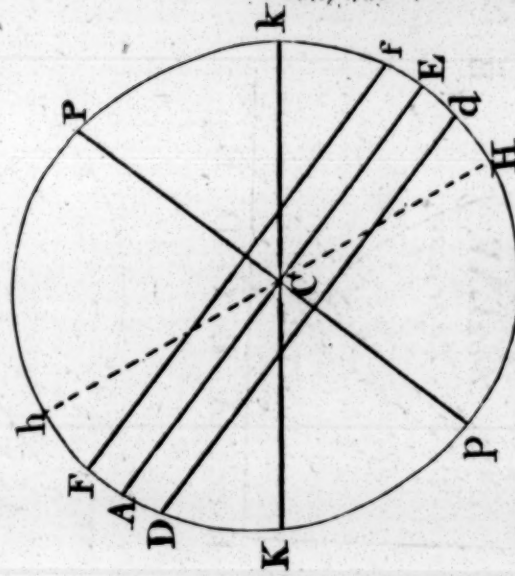


Fig. LXVI.  
Page 275.





# Of the Difference of Heat and Cold. 233

Atmosphere in the Winter than in Summer (as is evident from viewing the same in the second and fourth Position of the Earth in the Scheme) and therefore must be, when arrived to us at L, more weak and faint, in the first, than in the latter Case \*.

A. Sir,

\* 1. The Numbers above, viz. 10,  $7\frac{1}{2}$ , 3, shew the comparative Intensity of Heat of the Sun's Rays, under the several Altitudes TO, EO, and VO, simply, or in themselves considered: but if we would know what Proportion all the Heat of one whole Day bears to all the Heat of any other, it is a Problem of another sort.

2. This Proportion is expressed by the Areas of two Figures ABC and DEF (in Fig. LXI. on Plate XX, fronting p. 233.) the Bases of which, AB and DE, are the Times of the Sun's Continuance above the Horizon; and the Perpendiculars erected thereon, and connected by the Curves ACB and DFE, are the Times of his several Altitudes for the given Days; that is, the Heat of one Day is to the Heat of the other, as the Sum of all the Sines of the Sun's Altitude on the first Day, is to the Sum of all the Sun's Altitudes on the other.

3. But to express this more readily for any Day, the incomparable Dr. Halley has invented a general Rule or Canon, which he has given with its Demonstration in *Philosoph. Transf.* N<sup>o</sup> 203, which, as being very curious and important, I shall here explain and exemplify.

4. The Rule is: Multiply the Sum of the Sines of the Meridian Altitudes in any two opposite Parallels into the Sine of the Semidiurnal Arch; also multiply their Difference into the same Sine; the Sum of these two Products for the Summer, or their Difference for the Winter, is as the Sum of all the Sines of the Sun's Altitude, or as the Heat of the Day proposed.

5. For Example: Let the Proportion of Heat be sought for the 10th of June and December, when the Sun is in the Tropics of Cancer and Capricorn, for the Lat. of  $51^{\circ} 32'$ . Then,

|                                     |                            | Nat. Sines. |
|-------------------------------------|----------------------------|-------------|
| The Sun in Cancer, Mer. Altitude is | TO = $61^{\circ} 58'$      | =,882674    |
| The Sun in Capricorn, Mer. Altitude | VO = $14^{\circ} 58'$      | =,258257    |
| The Sum of these Sines is           | — — —                      | 1,140931    |
| Their Difference is                 | — — —                      | 0,624417    |
| The Mot. from 12 to 6 is            | $90^{\circ} 0' = TG$ ;     |             |
| The Ascen. Diff. is then            | $33^{\circ} 11' = GX$ ;    |             |
| The Sum is the Semidiur. Arch       | } $123^{\circ} 11' = TX$ } | Sine        |
| for the Summer Day                  |                            |             |
| The Diff. is the Semidi. Arch       | } $56^{\circ} 49' = VZ$ }  | 0,836923.   |
| for the Winter Day                  |                            |             |
|                                     |                            | Again,      |



# 234 The PHILOSOPHICAL GRAMMAR.

A. Sir, you need say no more; I am sufficiently convinced there is abundant Reason for the

Again, the Radius being  $\frac{1,000,000}{6,283,185}$   
 The Circumference of the Circle will be  $\frac{1,000,000}{2,149,955}$   
 And the Measure of the Summer Arch  $123^{\circ} 11' = 2,149,955$   
 And the Measure of the Winter Arch  $56^{\circ} 49' = 0,991,683$

6. Having thus prepared the Numbers, then, according to the Rule, the Product of 1,140,931 by 0,836,923 added to the Product of 0,624,417 by 2,149,955, is equal to 2,297,34, which expresses the Heat of the Summer's Day. In like manner, 1,140,931 by 0,836,923 subtracted from 0,624,417 by 0,991,683, leaves 0,338,95 for the Heat of the Winter's Day. But these two Numbers 2,297,34 and 0,338,95 are to each other very nearly in the Ratio of 7 to 1, which shews that the Quantity of Heat on *June* the 10th is seven Times greater than that on *December* the 10th, all other Circumstances being alike.

7. According to this Rule Dr. Keill has computed the Heat of the Sun for every five Degrees of its Declination *North* and *South*, at the Latitude of  $51^{\circ} 0'$  as in the Table here adjoined.

| Sun's Declination. | North.  | South.  |
|--------------------|---------|---------|
| 0                  | 1.25874 | 1.25864 |
| 5                  | 1.47393 | 1.04839 |
| 10                 | 1.69293 | 0.84508 |
| 15                 | 1.91489 | 0.65091 |
| 20                 | 2.13919 | 0.46916 |
| $23\frac{1}{2}$    | 2.29910 | 0.37980 |

8. Dr. Halley did also from this Rule calculate the annexed Table, shewing the Degree or Quantity of Heat at every ten Degrees of Latitude for the *Equinoctial* and *Tropical Sun* both Summer and Winter; from whence also an Estimate may be made for the intermediate Degrees.

| Lat. | Sun in $\varphi \approx$ | Sun in $\sigma$ | Sun in $\psi$ |
|------|--------------------------|-----------------|---------------|
| 0    | 20000                    | 18341           | 18341         |
| 10   | 19696                    | 20290           | 15834         |
| 20   | 18794                    | 21737           | 13166         |
| 30   | 17321                    | 22651           | 10124         |
| 40   | 15221                    | 23048           | 6944          |
| 50   | 12855                    | 22991           | 3798          |
| 60   | 10000                    | 22773           | 1075          |
| 70   | 6840                     | 23543           | 000           |
| 80   | 3473                     | 24673           | 000           |
| 90   | 0000                     | 25055           | 000           |

9. From these two Tables Dr. Keill has well observed the Advantages arising from the present *oblique Course* of the Sun in the *Ecliptic*, above what could have been enjoyed had the Earth had a *right Position*, or the *Sun moved continually in the Equinoctial Line*, as Dr. Burnet, and some other *Theorists*, pretend it did.

To front Page 234.

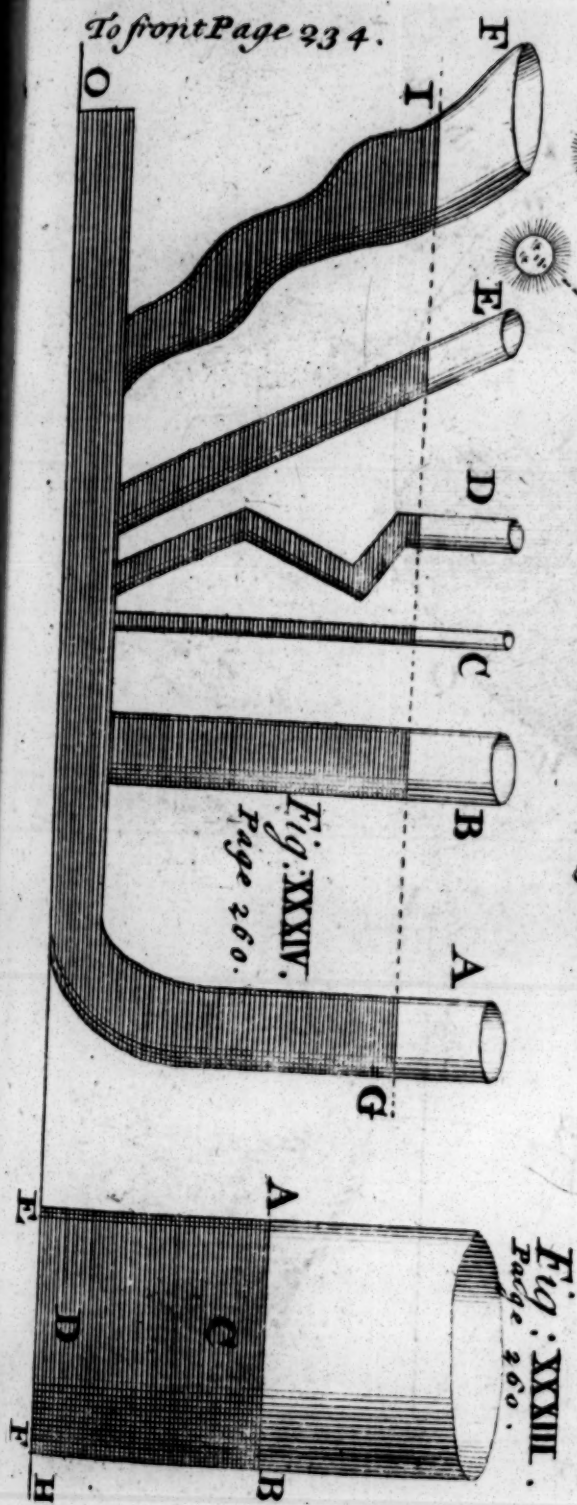


Fig. XXXIV.  
Page 260.

Fig. XXXIII.  
Page 260.

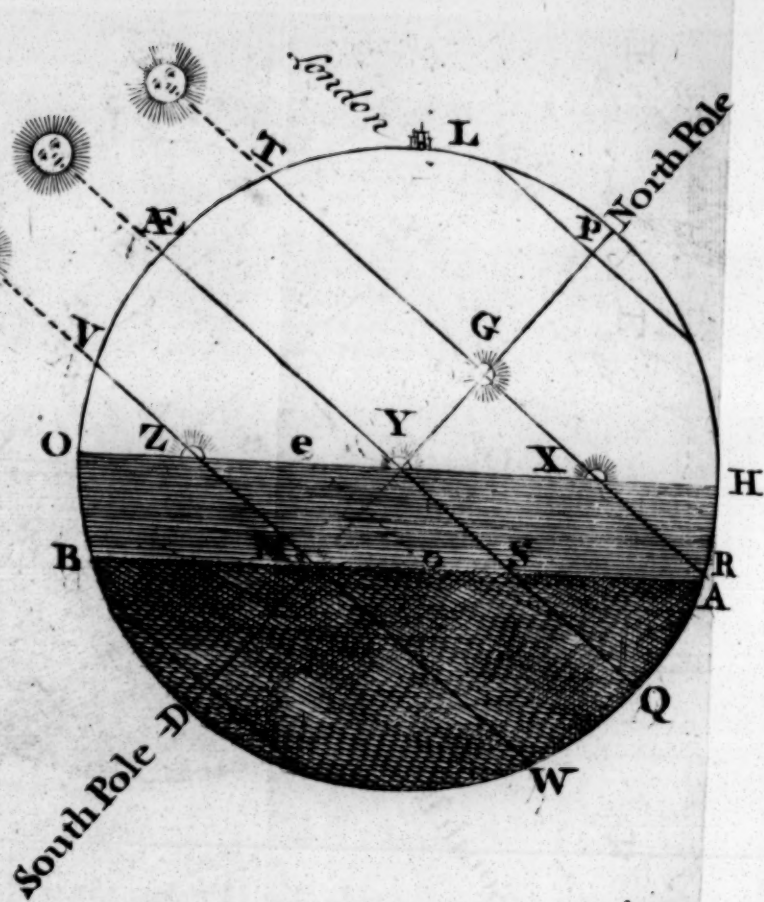


Fig. XXXI.  
Page 224.

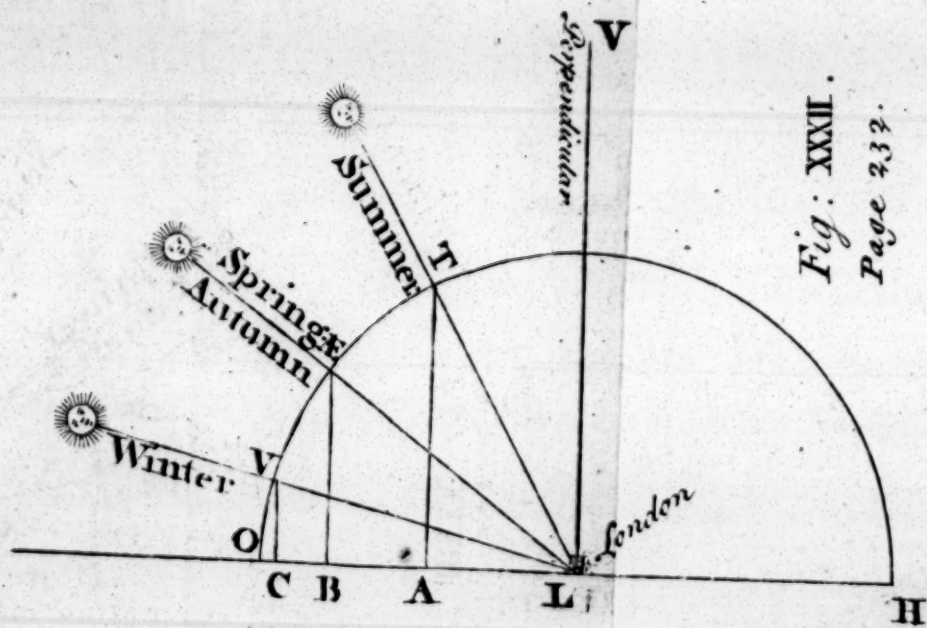


Fig. XXXII.  
Page 232.

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ONE



*Of the Difference of Light and Heat.* 235

the Differences of Light and Heat, and all the Variety of Seasons through the Year, though I never was so happy as to understand it before: We will now proceed to discourse of the internal Substance of the *Globe*, if you please; for I have several Matters of great Importance to enquire of you about, relating to its *Constitution, Texture*, and various *constituent Parts*.

B. *Sir*, none will more gladly take the Pleasure to resolve you, according to the Judgments of the best Philosophers of the Age, than your humble Servant: Pray therefore make a Beginning.

10. For from the first Table it is evident, the *Sum* or *total Heat*, which the Earth receives in Lat.  $51^{\circ}$  N. while the Sun describes any two opposite Parallels, is greater than the Heat of two Equinoctial Days there; for Example, the Heat of the Sun in the 20th Degree of North Declination is 2,13919, and in the 20th Degree of South Declination, it is 0,46916, the Sum of both these, is 2,60835, which is greater than 2,51728, the double of the Heat of an Equinoctial Day 1,25864. And, by the second Table, it appears all Latitudes beyond 45 Degrees enjoy this Benefit, and they alone need it.

11. Again, the same Gentleman proves that the *Torrid Zone*, and to near 46 Degrees in the Temperate Zones, the Heat of the Sun is *less* in the present Case than it would have been in the other. Thus the Sun's Heat describing both the *Tropicks*, to those under the *Equator*, is twice the Number 18341, *viz.* 36682; but the Heat of two Equinoctial Days is 40000, which is a great deal more than the other, and therefore the present Position of the Earth is most convenient for them, and consequently for all the People of the Earth, and proves it to be that which it first received from the Hands of its *All-wise Former*. See Dr. Keill's Exam. of Dr. Burnet's *Theory of the Earth*, p. 70 to 76.

## C H A P. II.

GEOGRAPHY, *or the PHILOSOPHY of the CONSTITUTION, TEXTURE, and constituent PARTS of the EARTH, describing the various STRATA'S of EARTHS, FOSSILS, MINERALS, METALS, STONES, and other subterraneous SUBSTANCES.*

A. **P**RAY, what is the internal Make and Constitution of the Globe of our *Earth*?

B. The *Earth*, generally speaking, is constituted of the two Substances of *Earth* and *Water*; the *Water*, as the lighter Part, possessing the greatest Part of its Superficies; and the *Earth* being the heavier Body, making up the internal Composition; about which it is, I presume, you here solely enquire\*.

A. Yes, what I would know is, of what the internal solid Body of the *Earth* doth consist?

B. To this I can only answer, that so far as it is within our Scrutiny near the Superficies, we find it to consist of different *Strata*, or *Layers* of *Eartbs*, *Minerals*, *Metals*, *Ores*, *Stones*, and various other compound Bodies both hard and soft: But what the more internal Parts or Composition of it may be, we can tell but very little: However, the deeper you go, the solider and more compact you find its Matter to be, and the more firmly and strongly does it cohere together; yet it is very certain, that within the Entrails of the *Earth* are many Caverns, Recesses, Windings, Conveyances, and vast Recep-

\* See a noble Description of the first Formation of the Earth and the Heavens from their *Chaotic* State, in *Ovid's* Princip. Metamorph. Lib. I. and *Milton's* Paradise Lost, Book III. ver. 709; and Book VII. ver. 216, to the End.

*Of the internal Parts of the Earth.* 237

tacles of Water, *sulphureous Substances*, &c. which are often the Cause of *Earthquakes*, and supply *Vulcanoes* with their fiery Eruptions, as *Mount Ætna*, &c \*.

A. What do you suppose to be in the very Middle of the *Earth*; that is, in and about its Center?

B. No body can certainly tell; the *Earth's* Center is near 4000 Miles from us, and we can penetrate towards it but a few Fathoms; how very unlikely then is it, we should know any Thing at such a vast and impervious

\* Sir *Isaac*, mentioning several Experiments made with combustible and explosive Substances, says; — “ By these Experiments compared with the great Quantity of *Sulphur* with which the Earth abounds, and the Warmth of the interior Parts of the Earth, and *hot Springs*, and *burning Mountains*, and with *Damps*, *mineral Coruscations*, *Earthquakes*, *hot suffocating Exhalations*, *Hurricanes*, and *Spouts*, we may learn, that *sulphureous Steams* abound in the Bowels of the Earth, and ferment with Minerals, and sometimes take Fire with a sudden *Coruscation* and *Explosion*, and if pent up in subterraneous Caverns, burst the Caverns with a great Shaking of the Earth, as in springing of a Mine. And then the Vapour generated by *Explosion*, expiring through the Pores of the Earth, feels *hot* and *suffocates*, and makes *Tempests* and *Hurricanes*, and sometimes causes the Land to *slide*, or the Sea to *boil*, and carries up the Water thereof in Drops, which by their Weight fall down again in *Spouts*. Also some *sulphureous Steams*, at all Times when the Earth is dry, ascending into the Air, ferment there with *nitrous Acids*, and, sometimes taking *Fire*, cause *Lightning* and *Thunder*, and other *fiery Meteors*.” Optics, Book III. Query 31.

See several surprising Accounts of *Water-Spouts* in the *Mediterranean*, in *Philos. Transf.* N<sup>o</sup> 277. Two in *Yorkshire*, N<sup>o</sup> 281, 284. One in *Lancashire*, N<sup>o</sup> 363. Another in the *Downs*, N<sup>o</sup> 270. That the Reader might have some Idea of these Spouts, I have here given the Figure of one, *Fig. LXII.* on *Plate XX*, fronting p. 233, where AB is the Cloud whence proceeds the curved black Spout C; D is the Water of the Sea, which at the Spouting of the Cloud boils up, and rises in the Form of a solid Pillar to meet the Spout; GG is the Water of the Pillar, or Column D, scattered round about the same like Smoke or the Falling of a *Jette d'Eau*; EF is the Surface of the Sea.

Distance?



Distance? However, the learned Dr. *Halley* has made it very probable, that a great *magnetic Body*, or *Load-Stone*, doth possess the central Parts of the *Earth*; which occasioneth the *Variations* and *Declinations* of our *magnetic Needles*, which always conform themselves to the Site and Direction of this *central Magnet*, or *Load-Stone*; which is supposed to deviate from the *North* and *South* Points, and from the horizontal Position, with respect to us \*.

*A.* If that be so, it is very wonderful, and a noble Discovery: But, pray, what is it binds the several Parts of the *Earth*, or makes them cohere so closely together?

*B.* The Coherence of the *Earth* is entirely owing to the Power of Gravity, or the Weight of its constituent Parts; whence, as I before said, it is reasonable to believe the most weighty and solid Bodies lie nearest the Center of the *Earth*, as being the Center of Gravity itself.

*A.* Well then, since the more interior Parts of the *Earth* are so little known, we leave them, and content ourselves with what is to be known near the Superficies of it on which we live; and, pray, what do you first observe thereof?

*B.* That it does consist of Bodies of a heterogeneous or different Nature intermixed with one another of different specific Gravities, disposed in Manner of *Beds*, which are called *Strata*, or *Layers* of *Earth*, *Stones*, *Minerals*, &c. one under another.

\* See a large Dissertation on this Subject, and the whole Theory of the *Magnetical Variations* of the *Needle*, by the said learned Dr. *Halley*, in *Philos. Trans.* N<sup>o</sup> 148 and 105, or the same transcribed into *Harris's Lexicon*, under the Word *Variation*.

*A.* Pray

A. Pray in what Order do these *Strata*, or Beds of *Earth*, &c. lie among themselves?

B. That they do not lie in Order of their specific Gravities, is evident (and so not every where alike) from the Order of those observed in digging a Well at *Amsterdam* 232 Feet deep; which was thus; seven Feet of Garden Mould; nine of Turf, or Peat; nine of soft Clay; eight of Sand; four of Earth; ten of Clay; four of Earth; ten of paving Sand; two of Clay; four of white Lome; five of dry Earth; one of muddy Earth; fourteen of Sand; three of a Sandy Clay; five of Sand mixed with Clay; four of Sea-Sand mixed with Shells; then 102 of Clay together; and, lastly, thirty-one of Lome: Thus you see the different Make of the outward Parts of the *Earth*, which is very different in different Places\*.

A. Pray how came the Disposition of those various *Strata*, or Beds of *Earth* and *Minerals*?

B. This is not known as to the Time; some say at the Creation, others at the Flood; others supposed, that in the *chaotic* State of the *Earth* the heavier Bodies subsided, and lay in this Order by the Laws of Gravitation; but Experience rather contradicts than confirms this *Hypothesis*.

A. What Distinction, or Division, do you make of earthy Substances or Bodies?

B. They may be reduced to those general Heads: 1. *Earths*. 2. *Ores*. 3. *Fossils*. 4. *Mi-*

\* See *Varren*. Geog. Gener. Lib. I. Cap. 7. Prop. 7. Also read Dr. *Woodward's* Natural Theory of the Earth; and Dr. *Arbutnot's* Examination thereof, and his Comparison of Dr. *Woodward's* and *Steno's* Hypotheses, which is well worth the Reader's perusing.

*nerals. 5. Metals. 6. Stones. 7. Extraneous Bodies or Substances.*

*A.* What do you include under the first general Head of *Earths*?

*B.* All those softer earthy Substances we call *Clay, Lome, Marl, Sand*, and different Species of *Earths*, as *Terra-Japonica, Lemnia, Armenia, &c.*

*A.* Pray what do you think to be the Cause of those Differences of earthy Substances now mentioned?

*B.* The Reason why they are differently hard, soft, coloured, qualified, &c. ariseth from different Degrees of the universal and specific Properties of the original constituent Particles of Matter, which each different Species possesseth in a different Measure; and this is the most that can be known of this Matter.

*A.* What do you include under the second Head of *Ores*?

*B.* Those *Earths* which contain considerable Quantities of metallic Particles; being that which is dug out of Mines, and whence Metals are extracted, and is denominated accordingly, as *Gold-Ore, Silver-Ore, &c.*

*A.* How came the *Earth* to be enriched with the Seeds of those metallic Substances?

*B.* No doubt by the all-wise Creator, for the manifold Uses of Mankind.

*A.* What terrestrial Bodies do you intend by *Fossils*?

*B.* Though *Fossils* be a general Name for every Thing which is dug out of the *Earth*; yet I here intend thereby, 1. *Salts*, 2. *Sulphurs*, and



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and such like Bodies, which cannot be so well reduced to the Heads of *Minerals, Metals, and Stones* \*.

A. What is the Nature of *Salt*, and the Kinds of it?

B. *Salt* (saith *Monf. Lemery*) is a fixed incombustible Substance, that gives Bodies their Consistence, preserves them from Corruption, and renders Bodies savoury more or less as it is diversly mixed in them; there are various Kinds of *Salts*, as fixed, volatile, essential, and foffile; and saline Substances, as *Alum, Borax, Nitre, Tartar, Vitriol, and Sal Ammoniac* †.

A. Pray give me some short Account of the Nature of these several Kinds of *Salts*.

B. I will, but it must be very brief, for want of Time.

\* The great *Boerhaave* distributes Fossils into two Kinds, *Simple and Compound*.

*Simple Fossils* are such whose Parts, howsoever divided, are all of the same Nature; that is, of the same Gravity, Magnitude, Figure, Hardness, and Mobility; of these he reckons four Sorts, viz. *Metals, Salts, Stones, and Earths*.

*Compound Fossils* are those which may be divided into different or dissimilar Parts, or are of different Figure, Weight, Magnitude, &c. and these are, (1.) All hard Sulphurs, as *Brimstone, Arsenic, Orpiment, Bitumen, Asphaltum, &c.* (2.) All liquid Sulphurs, as *Pis asphaltum, or Jew's Pitch, Naptha, Petroleum, &c.* (3.) *Semimetals, or Minerals.* (4.) Bodies combined out of the preceding Fossils, either simple or compound. *New Method of Chymistry, Page 54.*

† Dr. *Boerhaave's* Definition of Salt is this: *Salt is a foffile Body, fusible by Fire, and congealable again, in the Cold, into brittle Glebes or Crystals; soluble withal in Water, so as to disappear therein; never malleable; and having somewhat in it which to the Organ of Taste affords a Sensation of Acrimony or Sharpness.* Theor. of Chymistry, Page 105.

Also in Page 113, he saith, the Elements or common Principles of Salt, are an *acid Spirit*, and an *insipid Earth*, into which all are resolvable but the simple Fossils, as *Salt-Petre and Borax*.

Q

1. Fossile

1. *Fossile Salt*, is that which is called *Salt Gem*, by Reason of its Transparency, and is altogether like the *Salt* we use with Food; it is dug out of the Mountains in many Places, as *Russia*, *Poland*, *Catalonia*, *Persia*, and in the *Indies*.

2. *Fixed Salt*, is that which remains after Calcination, and doth not rise, or is not rarefied and exhaled by Heat.

3. *Volatile Salt*, is that which easily riseth, and flieth off in insensible Steam and Vapour; such are the *Salts* of Animals.

4. *Essential Salt*, is that which is obtained from Plants by CrySTALLIZATION; and is a natural *Salt* between *fixed* and *volatile*.

5. *Alum*, or *Rock Alum*, is a very binding *Salt*, found in the Veins of the Earth in many Places of *Europe*; being taken thereout in large transparent Pieces.

6. *Borax*, a green-coloured mineral *Salt*, found in the Veins of *Brass*, *Silver*, or *Gold Ore*.

7. *Nitre*, or *Salt-Petre*, is a *Salt* impregnated with abundance of Spirits out of the Air, which renders it *volatile*; it is found among the Stones and Earths of old Buildings; and is sometimes generated from Urine falling on Stones, &c. It is the Spirit of this *Salt* that kindles the Sulphur into a Flame in *Gunpowder*, *Lightning*, &c.

8. *Tartar*, is a terrestrious *Matter*, or earthy *Salt*, which sticketh to the Sides of Vessels, being separated from the Liquor by Means of its Fermentation; as that in *Wine Casks*, &c.

9. *Vitriol*,

9. *Vitriol*, is a *Fossil*, compounded of an *acid Salt*, and *sulphureous Earth*; there are four Sorts of it: 1. *Blue*, found in the Mines of Copper in *Hungary*, and *Isle of Cyprus*. 2. *Green*, found in *Germany*, *Italy*, and *England*. 3. *White*; and 4. *Red Vitriol*. This last was brought to us lately out of *Germany*, and is called *natural Colcothar*, or *Chalcitis*.

10. *Sal Ammoniac*, is either natural or artificial; the Natural is found in many Parts of *Africa*, and very hot Places under the torrid Zone; the Artificial is made at *Venice*, and divers other Places.

A. Please, in the next Place, to tell me what *Sulphur* is, and the Bodies you call *sulphureous*.

B. *Sulphur* is an inflammable *Fossil*, found in many Places in *Europe*, especially in *Sicily*; is of two Sorts: 1. The *Greyish*, called *Quick-Sulphur*; it is a Sort of Clay, apt to crumble, soft, and ready to take Fire; it consists of an *Oil*, an *acid Salt*, and *Earth*. 2. *Yellow*, or common *Sulphur*, called *Brimstone*; this containeth much *Oil*, an *acid vitriolic Salt*, and but little *Earth*.

A. Pray, Sir, what do the *Chymists* mean by that Principle they call *Sulphur*; not *Brimstone* sure, do they?

B. No, no; they mean an *Oil*, which is called *Sulphur*, by Reason of its Inflammability, and is a sweet, subtile, unctuous Substance, which is said to cause the Diversity of Colours and Smells, and to give Beauty or Deformity to Plants, &c. according to its Disposition in Bodies.

A. What Bodies do you reckon amongst the sulphureous Kind?

Q 2

B. These



B. These following : *Arsenic*, *Bitumen*, and its various Kinds, as *Ambergrease*, *Asphaltos*, *Naptha*, *Amber* ; also *Petroleum* is reckoned of this Class.

A. Pray rehearse me also a short Account of the Nature of these Bodies.

B. I design it ; which take as follows :

1. *Arsenic*, is a fossile Substance, consisting of much *Sulphur*, and some *caustic Salts* ; it is of three Sorts, the white, or proper *Arsenic* ; the yellow, called *Auripigmentum* ; and the red, called *Sandaracha*.

2. *Bitumen*, is a Kind of Pitch, or slimy Clay ; it is very much of the Nature of *Sulphur*, being very inflammable : It is of two Sorts, one liquid, which swimmeth like Oil on Water ; the other more hard and compact, is dug out of the Earth.

3. *Ambergrease*, is a Kind of *Bitumen*, found in many Places on the Sea-shore ; it grows hard in the Sun-Beams ; the best Sort is grey when dry, easily softens in the Heat, and appears blackish when wet.

4. *Asphaltos* : This is that slimy bituminous Substance, of a purple Hue, which is found in the *Lake of Sodom*, or *Dead-Sea*, in the *Land of Palestine* ; from whence its Waters are said to stink to that Degree, that no Fish can live in them, nor the Birds in the Air fly over them, and live.

5. *Naptha*, is another Sort of *Bitumen*, being liquid ; but somewhat more apt to take Fire, and is more hardly extinguished.

6. *Am-*

6. *Amber*, is also a kind of coagulated *Bitumen*; though it is evident, its first State is soft and viscous, from the Flies, Ants, Straws, &c. found in its Texture; it is different in Colour, as white, yellow, and black; is found in small Currents near the *Baltic Sea*, and the *Dutchy of Prussia*: It hath an electric Property; for, being rubbed, it will attract Hairs, Feathers, Straws, &c.

7. *Petroleum*, or *Oil of Peter*, is of a sulphureous Nature; it distils through the Clefts of Rocks in *Italy*, *Sicily*, and *Provence*; and seems to be an *Oil* of some *Bitumen*, which the *subterranean Fires* have raised.

A. Sir, I thank you: I should be glad, in the next Place, to be informed a little of those Bodies of the *fourth* Head, called *Minerals*.

B. Those are such Sort of *Fossils* as are not inflammable, nor ductile, nor to be melted, or liquefied; but are hard and brittle, may be reduced to a Powder, or, by Fire, calcined to a Calx; of which, the following are most worth Notice.

1. *Marcaffite*, or *Bismuth*, is a metallic Matter, white, smooth, hard, brittle, sharp; is of a sulphureous Nature, like to Tin; it is disposed into Facets, or shining Scales, like Pieces of Glass; hence called Tin-Glass.

2. *Antimony*, is a Mineral, consisting of a *Sulphur*, and a Substance approaching to that of Metal, containing also (as it is thought from its emetic Quality) an *acid Salt*; it is found in

divers Places, in *Transylvania, Hungary, France,* and *Germany.*

3. *Cinnabar*, is a Mineral, consisting of a Mixture of *Quicksilver* and *Sulphur*, sublimed together by Means of a subterranean Heat, in the same Manner as the *Chymists* make artificial *Cinnabar*; it is, while in the Lump, of a brownish Colour, but, when powdered, is of a very high red.

4. *Chalk*, is a mineral Earth, of a bituminous Quality, yet is an *alkali Salt*; is of a soft and friable Texture in many Places; and in others of a hard and massy Substance, called *Quarry*; it every where abounds in Hills, Ridges of Mountains, and other Places.

5. *Coal*; this is a Mineral, consisting of *Sulphur* in great Quantities, mixed with a terreftrious Substance; it is a Kind of a *resinous Bitumen*, of a middle Consistence, not easily inflammable, yet will run and melt with Heat; its Texture is not soon destroyed by Fire, but is thereby at last reduced to a Calx, or Cinder; it is dug in great Quantities out of the Earth in *England*, and other Places, and serves chiefly for Fuel \*.

A. What is the proper Nature of *Metals*?

B. A *Metal* is a simple fossile Body, that *fuses* and becomes *fluid* by *Fire*, and by Cold *coagulates* and *hardens* into a *solid Mass*, capable of *distending* under the Hammer. The Bodies

\* The Principles of all Fossils (says the same learned Author) are (1.) *Mercury*, as the *Basis* of many of them. (2.) A *subtile Sulphur*, which coagulates or fixes the Mercury. (3.) *Salt*; and (4.) *Earth*. Theor. of Chymistry, Page 139.



to which this Definition belongs in every Part, are but *six*; viz. *Gold, Lead, Silver, Copper, Iron, and Tin*; to which the Chymists add *Mercury* or *Quicksilver*, tho' it seems to be of itself a peculiar Species of *Simple Fossils*.

*Gold* is the noblest of all Metals, and is distinguished by the following *Properties* or *Characteristics*. 1. It is the *heaviest* of all Bodies in Nature, and its *Weight* is *inimitable*. 2. It is the most *ductile* and *malleable* of all Bodies. 3. It is the most *fixed* and *pure*, or *loses the least* in the Fire, of any Bodies. 4. It requires a vehement Fire to fuse it, tho' less than *Iron* or *Copper*. 5. It is dissolvable in no *Menstruum* but *Aqua Regia*, and *Mercury*. 6. It readily and spontaneously *attracts* and *absorbs Mercury*. 7. It does not, when fused with *Lead* and *Antimony*, dispose or fly off with them in Fume, but remains fixed. 8. Its *Sound* when pure is not *clear*, but rather *obtuse*, like that of *Lead*. 9. It is the *simplest* or *freest* from *Mixture* of *heterogeneous Parts*, of all Compound Bodies yet known. 10. It is of a fine *yellow Colour*, tho' subject to alter and fade. 11. It is found sometimes *pure*, in *Glebe* or *Gold Clods*, as in *Hungary*, and *Mountains of Chili*; sometimes in a *pure Dust* or *Sand*, as in the Bottoms of some Rivers in *Guinea*; and lastly, in whitish *Clods* dug out of Mines 150 or 160 Fathoms deep, intermixed with other Minerals, as *Antimony, Vitriol, Sulphur, &c.* 12. Gold is liable to *Rust*, as is found by holding it over the *Fumes* of *Sea Salt*. These are the *Criteria* of *Gold*, and are all of them always found pertaining to that Metal.

Q 4

*Mercury,*

*Mercury*, by reason of its *Weight*, comes next to be considered; its Characters are, 1. That it is the *heaviest* of all Bodies except *Gold*. 2. It is the most *fluid* of all Bodies; or its Parts separate and recede from each other with the least *Force*. 3. It is *divisible* into the *minutest Part* of any Body. 4. It is extremely *volatile*, being convertible into *Fumes*, even with a *Sand-beat*. 5. It easily penetrates, and intimately adheres to *Gold*; not so easily to any other Metals; difficultly to *Copper*; and not at all to *Iron*. 6. Of all other Fluids, it is found capable of the *greatest Cold* and *Heat*. 7. It is yet, by reason of its great *Fluidity*, incapable of *congealing* or *freezing*. 8. It *dissolves* in almost all *Acids*, and unites itself with them. 9. It is the most simple or unmixed of any Bodies after *Gold*. 10. It is *free* from any *Sharpness* or *Acrimony*. 11. It is found in great Plenty in the Mines of *Friuli* in *Italy*, in the Form of *ruddy Clods*, called *Cinnabar*; in *hard stony* Glebes; and lastly, *pure*, called *Virgin Mercury*, running in Veins and Streams about in the Mine.

*Lead*, as to its *Weight*, comes next; whose chief Properties are, 1. That, next to *Gold* and *Mercury*, it is the *heaviest* of Bodies. 2. Of all Metals it is the *softest*, and therefore very *ductile* and *flexible*. 3. It melts the *soonest* of all Metals. 4. It very *easily dissolves* in almost all *weak Acids*, but not so readily in *strong ones*. 5. It *dissipates* all Metals melted with it, but *Gold* and *Silver*, or carries them off in *Fumes*. 6. Of all Metals it is the least *sonorous*, and diminishes the *Sound* of others when mixed with it. 7. It hath  
the

*Of Mercury, Lead, Silver, Copper.* 249

the least *Elasticity* of any Metal. 8. It is sometimes found *pure*, but oftener in *Mineral Ore*, which is a Sort of blackish fatty Earth, difficult to fuse. Of Lead Mines there are abundance in *Germany, Hungary, and England*.

*Silver* hath the following Characters. 1. It is next to Lead in *Weight*. 2. Its *Fixity* is next to that of Gold. 3. As also its *Ductility* and *Malleability*. 4. Its *Fusibility* by Fire is very easy, tho' more difficult than that of Gold or Lead. 5. It is dissolvable in *Aqua Fortis*, but not in *Aqua Regia*. 6. It *resisteth the Force of Lead in Fusion*, or is not dissipated in Fumes thereby. 7. It *resists* not the Force of Antimony, but volatilizes and flies off along with it. 8. It yields not much *Sound* when purified; being *less sonorous* than Iron or Copper, but more than Gold. 9. *Silver* is seldom found *pure*; sometimes in the Ore of Gold, Lead, and Copper, but ofteneft in a Kind of stony black Glebes, full of shining Streaks, as in the Mines of *Peru and Chili*.

*Copper* is a Metal of the following Properties or Characters. 1. It is next to Silver in Weight. 2. It is very *ductile* when pure. 3. It is of a beautiful *red Colour*, exceeding that of Gold. 4. Its *Fixity* in the Fire is greater than that of Lead or Tin, but less than that of Silver. 5. It is *difficult of Fusion*, much more than Silver; yet *ignites* before it fuses, which Silver does not. 6. It is dissoluble by all the Salt Menstruums known, whether *Acid, Alkaline, or Nitrous*, yea by *Water, Air, &c.* 7. If it be dissolved in *Acids*, it turns *Green*; in *Alkali, Red*; and



and by other Salts, *Blue*. 8. Its *Divisibility* is very great and surprising; for *one Grain* dissolved, will tinge with *Blue* above 530620 times its Bulk of Water. 9. It *flies off in Vapour*, being fused with *Lead* or *Antimony*. 10. It is the most *elastic*; and 11. The most *sonorous* of all Metals. 12. *Copper* is every where found, but most abundantly in *Sweden* and *Germany*, where there are whole Mountains of it; but the *richest Ore* is in the Mines of *Hungary*.

*N. B.* *Brass* is made of *Copper* thus: They calcine and pulverize *Calamine*, and mix it with a little Charcoal Dust; then they put seven Pounds of this Mixture into a melting Pot, with about five Pounds of *Copper* over it; then letting it down in a Wind-Furnace, after 11 Hours, it is drawn up again, the *Brass* being completed in the Dissolution.

*Iron* is the Metal to which the following Characters belong. 1. It is the *heaviest* of all Bodies after *Copper*. 2. It is the *least ductile*, the *hardest* and *most brittle* of all Metals. 3. It is *very fixed*, as to its metalline Part. 4. It *ignites long* before it *fuses*, and will not *fuse without Difficulty*. 5. The *more* it is *ignited*, the *softer* and *more malleable* it becomes, contrary to the Nature of all other Metals. 6. It is dissoluble by almost all Bodies in Nature, that have any Motion of Parts; as *Fire*, *Salt*, *Air*, *Dew*, *Water*, &c. 7. It is extremely *rubiginous*, or apt to contract *Rust*, by the *Action* or *Corrosion* of the aforementioned Bodies upon it. 8. If it be fused with *Lead*, *Antimony*, or *fixed Salt*, it readily dissipates into Fume, or vitrefies. 9. It is very *sonorous*.

rous and elastic, tho' inferior in these Respects to Copper. 10. Of all Bodies, it is the only one attracted by the *Loadstone*; and 11. It has a Kind of *Magnetism*, or is capable of attracting Iron itself. 12. Iron is found in Mines, which are very common in most Countries in *Europe*; as *Norway, Poland, Germany, France, England, &c.* and its *Glebe* or *Mercurialite* bears a near Resemblance to the *Loadstone*.

*Tin* is distinguished by the *Characteristics* following. 1. It is the *lightest* of all *Metals*, and the *heaviest* of all other Bodies besides them. 2. It is the *softest* of all *Metals* but *Lead*. 3. It has the *least Fixity* in the Fire of all *Metals*, and therefore loses the *most* of its *Weight*. 4. It is *fusible* by the least gentle Fire, and that long before *Ignition*. 5. It is easily *miscible* with other *Metals*, and diminishes their *Ductility*, except in *Iron*. 6. It will not *dissolve* in *Acids*, especially *strong ones*, without much Difficulty. 7. It is the *least sonorous* of any *Metals* but *Lead*; and yet it augments their Sound when mixed with them. 8. And tho' it is in itself very little *elastic*, yet when mixed with other *elastic* Bodies, it wonderfully increases their *Elasticity*. 9. *Tin* is principally found in *Cornwall* and *Devonshire*; and its *Glebe* or *Ore* is a *heavy spongy Stone*.

A. What are the Elements or Principles of which *Metals* consist?

B. The *Elementary* or *Component Principles* of *Metals* are reckoned two, viz. *Mercury* and *Sulphur*; *Mercury* as the *Basis* or *Matter* of the *Metal*; and *Sulphur* as the *Binder* or *Cement*, which renders it fixed and malleable. This *Mercury* is the same

as common *Quicksilver*, but only the most *defecate* and pure that is possible. But by the Principle *Sulphur* is to be understood, not the vulgar *fossile Sulphur*, but a peculiar Sort of Matter called the *Sulphur of Metal*, which is supposed to be the Matter of *Light* or *Fire*, which uniting with Mercury, fixes it; and according to the different Degrees of its Union and Coherence therewith, it produces different Sorts of Metals. To this may be added, that a *Burning-Glass* will separate a *vitresfiable Earth* from any the most perfect of Metals.

*A.* Well, *Sir*, I heartily return you Thanks; and, if you are not tired with talking so long, I should next be glad to hear you on the Subject of the sixth general Head, *viz. Stones*.

*B.* No, *Sir*, I am never tired on the Subjects of Mathematics and Philosophy; and therefore I will go on to enumerate some of the principal *Stones*, and hint to you the particular Properties of each of them.

1. *Marble*, is a curious Substance, arising from an earthy Juice, well purged, concocted, and digested in the great Laboratory of the Earth; a Body very compact and hard, and may be calcined to Powder, but cannot be melted.

2. *Alabaster*, is a Kind of Marble, but more soft and friable, and is combustible like Lime, but as ponderous and polite as Marble itself.

3. *Porphyry*, is another Species of Marble, variously coloured, somewhat lighter than Marble, yet very hard.

4. *Flint*,



4. *Flint*, is an exceeding hard Substance, generated from the pellucid Particles of Sand compacted together, and indurated; and may be put into Fusion; whence Glass is made.

5. *Crystal*, is a very pellucid transparent Gem; the most pure is found in the Tops of Rocks and Mountains, and dug out of the Bowels of the Earth also; it is not coloured, is softer than other Gems, and therefore shineth not much; it consisteth of an aqueous Substance, and is therefore easily liquefied and converted into Glass, saith *Cardan*.

6. *Adamant*, or *Diamond*, is in Colour and Figure much like *Crystal*, generated in the same Manner; but its Hardness far exceeds that of all other Bodies; for it will cut and penetrate the Texture of any of them; it has an electric Quality, in attracting Straws, Feathers, &c. being warmed by Attrition.

7. *Beryl*, is a Stone, much of the Nature of a *Crystal*, of a faint green Colour; found at the Root of *Mount Taurus*, in the River *Euphrates*, and in the *Indies*.

8. *Smaragdus*, an Emerald, of a lovely Green, and of so strong a Lustre, that it shineth in the Light of the Sun or Candles; it is very transparent, and said to tinge the Air with its Greenness.

9. *Carbuncle*, is a precious Stone of transcendent Lustre; being of a glowing fiery Colour, like a burning Coal, as the Name importeth.

10. *Ruby*, so named for its noble red Colour, is the most valuable of all precious Stones next the *Diamond*; it is said to be first white, and to grow

grow red gradually from a sanguine Juice, from which it is nourished and generated at first.

11. *Hyacinth*, or *Jacynth*, is a Species of the *Carbuncle*, of a red-lead Colour; it having its Name from a Flower of the same Colour.

12. *Amethyst*; this is near the Nature of an *Hyacinth*, is of a purple Colour, arising as it were from a Mixture of Red and Blue; they are very hard, and the harder the better.

13. *Sapphire* (from the Hebrew ספיר *specious, beautiful*) is a precious Stone of a lovely Azure, or sky-coloured Blue, found in many Places in the *Indies*.

14. *Topaz*; this precious Gem is reckoned to excel among all those which shine with a golden Colour.

15. *Sardius*, a Gem called the *Cornelian*, or *Cornelian Stone*, from its fleshy Colour; the best is found in *Sardinia*, whence the Name.

16. *Onyx*, a Gem partly pellucid, so called, because it expresseth the human Nail in Colour and Splendor.

17. *Sardonyx*, is a precious Stone, somewhat pellucid, and is thus named, as if made up of a *Sardius* and *Onyx* together; it is distinguished mostly by black, white, and sanguine Circles.

18. *Chalcedony*, was formerly reckoned a Sort of *Carbuncle*, but is now referred to the *Onyx*; it is very hard, and of a light cloudy Colour through its whole Body.

19. *Achate*; this is an opaque Gem, yet sparkling by reflected Light; and by various coloured

*Wonderful Properties of the Loadstone.* 255

coloured veiny Lines, resembles Trees, Rivers, Animals, &c. beautifully on its Surface.

20. *Jasper* is, like the *Achate*, opaque, and of various Hue; but the *Green* is the more general Colour of this Stone.

21. *Pearls* are Jewels, or precious Stones, bred in the Shells of Fish; of which there be various Kinds, not much to our Purpose here to recount \*.

A. But, *Sir*, I think in all your long Catalogue of *Minerals* and *Stones*, you have not mentioned the *Loadstone*.

B. No, *Sir*, I have not; the Reason is, because this most wonderful of all Fossils hath always merited a particular Consideration.

A. Be pleased then, *Sir*, to oblige me with a short Account of the Nature, and some of the chief Properties of this Stone.

B. The *Magnet*, or *Loadstone*, is a Mineral found in Iron Mines, which is somewhat of the Nature of Iron, but is not malleable, nor will it melt, but may be reduced to Powder, or calcined to a Calx; its Particles therefore are more rigid, hard and implicated, than those of Iron. The chief Properties of the *Magnet* are these: 1. The *Loadstone*, at Liberty, doth always put itself in a Position, respecting the Poles of the World, and the same Parts always tend to the same Pole. 2. This Stone doth not pre-

\* Whoever would see more concerning *Métals*, *Minerals*, *Stones*, and other Fossils, may meet with great Satisfaction in Dr. *Berhaave's* Chymistry, with Dr. *Shaw's* Notes, from Page 51 to 141 of the Theory; and in Dr. *Fr. Nicholl's* Observations on Mines and Minerals, in *Philos. Transf.* N<sup>o</sup> 401, 403. *Woodward's* Nat. Hist. of the World, Part IV.

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cisely point to the Poles of the Earth, but declineth a little *Eastward* or *Westward*, more or less. 3. Two *Loadstones*, placed at a certain Distance, approach to, or recede from, each other, as they are variously placed. 4. *Loadstones* do so attract each other, as to sustain one another pendent in the open Air, provided the *North* Pole of the one be opposed to the *South* Pole of the other. 5. Sometimes a lighter *Magnet* will sustain a heavier one pendent, though a heavier *Magnet* will not sustain a lighter one. 6. It is observed, this Virtue of turning to the Poles is not equally strong in all *Loadstones*, some doing it with greater Celerity than others. 7. There are observed some *anomalous Loadstones*, which seem to have more than two Poles, or Points of Direction. 8. The *Loadstone* attracteth Iron, as it were another *Loadstone*. 9. The magnetic Virtue is communicated to Iron or Steel by the Touch; thus a Needle, touched by the *Loadstone*, will always keep in a Position towards the *North* and *South*. 10. *Loadstones* are corrupted, if they lie long together, with *North* Pole to *North* Pole, or contrarily; they also lose their Virtue by being made red-hot in Fire, with many other Properties of less Note.

*A.* And pray, *Sir*, whence is this Mineral endued with this surprizing Virtue?

*B.* I cannot find any of the Philosophers can tell the formal Cause thereof; it is a Secret yet hid from Man, though he be blest with a Discovery of its Use \*.

*A.* Pray

\* As the Properties of the *Magnet* and the Experiments illustrating the same, are endless to recount; so the Authors who treat thereof,

A. Pray what Parts of the Earth are most productive of Minerals and Metallic Substances?

B. Mountains, which seem, as it were, designed as Matrices for the Generation and Maturation of Minerals and Metals; because in them the most useful Fossils are principally found.

A. Do Minerals, Metals, Stones, &c. grow in the Earth?

B. Undoubtedly: Yea, it is well known that divers Mines, when emptied of Stone, Metal, &c. have, after a while, recruited again. Also divers stony, sparry Ificles, and other stalactical Substances, may be daily seen engendered from the Exudations of some petrifying Juices out of the rocky Earth in great Caves; as I myself have seen in *Okry-hole* in *Somersetshire* \*.

A. Well, but to make an End, what may you mean by extraneous Bodies in the Earth, the Subject of the 7th and last general Head?

B. The various *Exuviae* of Fish, and other marine Animals; such as petrified *Echini*, *Glossopetrae*, *Cockles*, *Oyster-shells*, *Turbens*, *Scallops*, &c.

thereof, and the Hypotheses they advance for the Solution of those Properties are almost infinite. But they who desire a large Discourse on this surprizing Subject, may consult *Joan. Clerici* Phys. Lib. II. Cap 6. *Hauksbee's*, *Desaguliers's*, &c. Courses of Experiments. *Robault's* Physics, Part III. Chap. 8. *Jac. Ode*, Philos. Nat. Tom. II. Cap. 3. *Kircheri*, *Ars Magnetica*. *Whiston's* Doct. of the Magnet. *Stairii* Physiol. Explorat. XVIII. § 12 to § 37, inclusive. *Descartes*, *Opera Philosophica*, Part. IV. § 133, & seqq. *Institutio Philos.* Tom. III. Part. II. § 3. Cap. 4. *Regnault's* Conversat. Vol. I. Conv. 15, 16. *Lowthorpe's* Abridgment. Vol. II. Page 610. *Eames and Martyn's* Abridgment, Part II. Chap. 4. *Miscellanea Curiosa*, Vol. I. Page 43. *Harris's* Lexicon, and *Chambers's* Dictionary, at the Word *Magnet*. *Phil. Transf.* N<sup>o</sup> 368, 390, 414, 423, 389, 366, 371, 412.

\* See Mr. *Derham's* *Physico-Theology*, Book III. Chap. 2. the Notes.

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that are found in various Parts and great Depths of Earth, and are to be seen in the Cabinets of the Curious.

*A.* Pray, how came those Bodies at first intermixed with the Earth?

*B.* None can certainly tell; it is supposed at the Deluge, or by some general Inundation of the Seas, whereby the Earth was rendered soft, and those marine Bodies sunk therein, and were covered over; and by the petrifying Quality of the Earth, in Time, turned into Stone\*.

\* *Dr. Woodward* says, the *Echini* and other lighter Shells are very numerous and frequent in all the Chalk-Pits of *Kent*, *Surrey*, *Essex*, and other Shires; being found indifferently, from Top to Bottom, in Pits that were 100 Feet deep; and in *Wells* much deeper. Also that the *Conchæ*, *Pectines*, *Cochleæ*, and Shells of a like Gravity, are found in the Sand Stone of all Countries, yea, even in the very Middle of *Flints* themselves. *Nat. Hist. of the Earth*, Part I. Page 30, 31. Part IV. Page 183, &c.

It is common to find that the *Echini*, *Cochleæ*, *Conchæ*, *Pectines*, and other Shells, have their Cavities filled up with Ores, Flint, Spar, Vitriol, Sulphur, and other Minerals; these receive the specific Figures of the Shells, they are formed or moulded in. And these Stones are what Authors call *Echinities*, *Cochlites*, *Conchites*, *Pectinites*, &c.

*Steno*, in his Book *de Solido intra Solidum contento*, says, there were many marine Shells found in a Stone taken out of the *Forum Volaterranum*, which many Ages before had been brought thither for Building; and therefore it was certain those Shells could not have endured less than 3000 Years, and probably from the Flood.

See much on this Subject in *Dr. Woodward's History of the Earth*. *Steno's* Book above mentioned. The Theories of *Dr. Burnet* and *Mr. Whiston*. *Bartholini Specim. Philos. Nat.* Cap. 13. Pag. 130-133. *Philos. Trans.* N<sup>o</sup> 291, 305, 360, 368.



## C H A P. III.

HYDROGRAPHY, or the PHILOSOPHY of WATER; of the Laws of its PRESSURE and GRAVITY; of the SEA, its Origin, Roundness, Extent, Saltness, and Tides; of the Cause of FOUNTAINS, RIVERS, LAKES, and BATHS, with the Properties of their several Waters.

A. **W**HAT is the Original of *Hydrography*?

B. The Word is composed of ὕδωρ, *Water*, and γράφειν, a *Description*; and here signifies a philosophical *Description of Water*.

A. You have already described me the different Distinctions of Water on the Earth's Surface, and likewise the Cause of its *Fluidity* and *Volubility*; pray what then remains to be farther considered of *Water*?

B. In the first Place we must more particularly consider the Effects arising from Fluidity, and the Rules of Motion, called the *hydrostatic* and *hydraulic* Laws of the Gravity and Pressure of Fluids \*.

\* 1. The Word *Hydrostatics* is derived from ὕδωρ, *Water*, and στατική, the Science of *Weight*, from σταλέω, to weigh. Consequently, *Hydrostatics* imports the Science which is conversant about those Properties of *Water*, or any Fluids, which depend on, or result from the *Weight* or *Gravity* thereof.

2. *Hydraulics* is derived of ὕδωρ, *Water*, and αὐλός, a *Pipe*; for anciently the Organ and other Wind Instruments of Music were blown by Wind made by the Fall of *Water* instead of Bellows. Whence this Word in Time came to be applied to the *Art of making all Sorts of Engines for carrying or raising of Water, or which are worked or moved by Water*. And hence the ancient *Water-Engines* described by Hiron are called *Machinae Hydraulicae*, i. e. *Hydraulic Machines* or *Engines*.

*A.* What are those Effects you call the *hydrostatic Laws of Fluids*?

*B.* We have not Time to consider all, the chiefest are the following.

1. *The Surface of a Fluid contained in a Vessel abiding free, will become plane, or parallel to the Horizon: Thus the Surface AB, of the Fluid CD, will be parallel to the Horizon HO.*

2. *The upper Parts C press the lower Parts D, which sustain them; and this Pressure is always proportional to the Height of the Fluid AE. See Figures XXXIII. and XXXIV. on Plate XXI, fronting p. 234.*

3. *This Pressure on the lower Parts, from the Gravity of the superincumbent Liquid, exerts itself every Way, and every Way equally.*

4. *In several Tubes, having a Communication with each other, as ABCDEF, whether equal or unequal, straight or crooked, erect or oblique, a Fluid will rise to the same Height GI in all. Fig. XXXIV. on Plate XXI, fronting p. 234.*

5. *When Liquids of different Gravities are contained in the same Vessel, the heaviest lies at the lowest Place, and is pressed by the lighter, in Proportion to the Height of the lighter.*

6. *The Bottom EF, and Sides AEBF, all round a Vessel, are pressed by the Parts of the Liquid contained which immediately touch them; and that in Proportion to the Height of the Liquid, not at all regarding its Quantity. Fig. XXXI. on Plate XXI, as above.*

7. *A solid Body immersed in a Liquid, is pressed by the Liquid on all Sides; and that Pressure increases in Proportion to the Height of the Liquid*

quid above the Solid. Bodies very deeply immersed are, as it were, equally pressed on all Sides.

8. Any Body, which is heavier than an equal Bulk of the Liquid into which it is immersed, will sink or descend therein.

9. If the Body be lighter than an equal Bulk of the said Liquid into which it is immersed, it will ascend to the Top, or swim.

10. But, suppose the Body be equal in Weight with an equal Bulk of the Liquid, it will neither ascend or descend, but remain suspended in the Liquor, wherever it is placed.

11. All equal Solids, but of different specific Gravities, being immersed in the same Liquid, lose equal Parts of their Weight.

12. A Liquid acquires the same Weight which the immersed Solid loses.

13. The immersed Parts of Bodies swimming on the Surface of the same Liquor, are to each other as the Weights of the Bodies.

A. And, pray, how do you prove these Laws, and what are their Use?

B. They are founded on various Experiments; and their Use is to discover the different Weights or specific Gravities of Liquids and Solids, which is not only a very great and useful, but also a very pleasing and delightful Part of natural Philosophy\*.

A. Pray

\* The Proof of these Laws of Fluids is threefold, viz. (1.) *Physical*; which depends on a bare Contemplation of the Nature, Figure, and other Properties of the small Particles of Fluids, separately considered; and the *Phænomena* thence arising will evince the Truth of the said Laws. (2.) *Mathematical*; for by considering of Liquids as Solids, and dividing them into Planes, Columns, &c. and representing their different Heights, Gravities, and Velocities,



*A.* Pray how do you find or estimate the specific Gravities of Solids?

*B.* Thus, by the hydrostatic Balance *S*, *Fig. XXXV.* on *Plate XXI*, fronting *p.* 262, let there be prepared a Glass Vessel of Water *E*, and another Vessel *D*, whose Weight in Water must be precisely equal to that of the Weight *C*. Now the Weight *C* being affixed to the Scale *A*, the Solid, whose specific Gravity is desired, being first weighed in Air, must then be put into the Vessel *D*, which is then affixed to the Scale *B*, and immersed into the Vessel of Water; then put Weights into the Scale *B* till there be a just Equipoise. Now from its Weight in Air, subduct its Weight in Water, and the Remainder will be as its *specific Gravity* inversely; and thus the Ratio's or Proportion of the *specific Gravities* of several Bodies may be found.

*A.* As to the Manner of weighing those Bodies, it seems pretty easy to be apprehended from the *Figure*; but as to computing the Ratio's, I believe I could better understand that by Example.

*B.* Why then I will give you one. Suppose you take a Piece of Lead and a Piece of Ivory, each weighing 69 Grains in Air, but weighing

*cities*, by algebraic Characters, it is easy, by Rules of Art, to raise Theorems, which are so many Hydrostatic Laws. (3.) *Experimental*; for all those Laws are capable of Proof by innumerable *Experiments*. See the several Courses of Experiments, by Dr. *De'aguliers*, *Gravesande*, *Hawksbee*, *Worster*, &c. *Mariotte's Hydrostatics*, englished by Dr. *Desaguliers*. *Robault's Mechanics*, translated by *Watts*, Page 118. *Boyle's Hydrostatical Paradoxes. Compend. System of Nat. Philos.* Part 2. *Sinclair's Hydrostatics.* *Clarke's Notes to Robault's Physics*, Part I. Chap. 16. § 8. *Musschenbroek's Epit. Phys.* Part 2. *Ditton's New Law of Fluids.* *Switzer's Gen. System of Hydrostatics.* *Phil. Trans.* abridged, by Mess. *Eomes* and *Martyn*, Part I. Chap. 6. *Chambers's Dict.* and *Horris's Lexicon*, under the Words *Fluids* and *Hydrostatics*.

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To front Page 262.

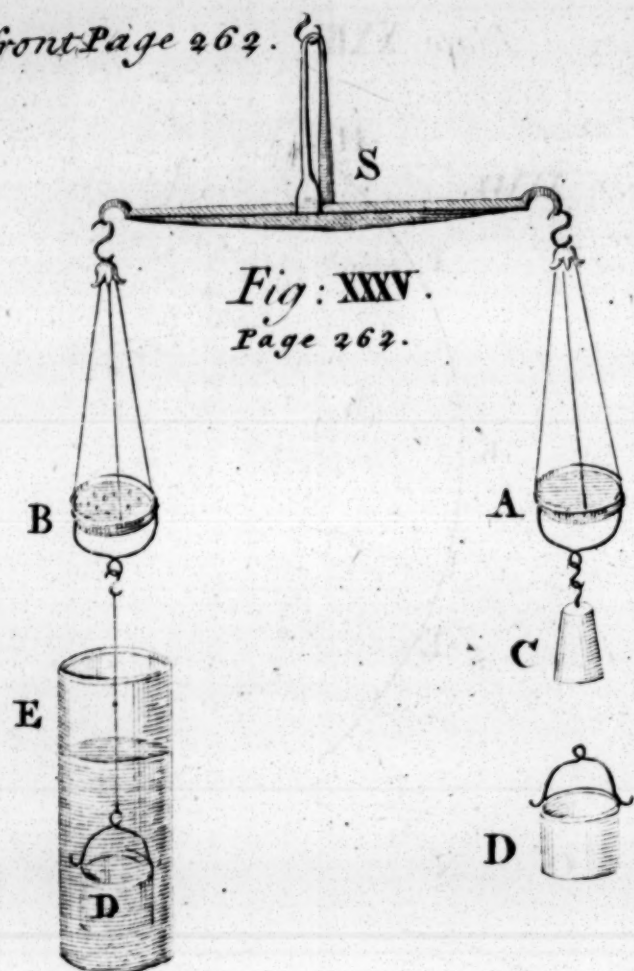


Fig. XXXV.  
Page 262.

Plate XXII

Fig. XXXVI.  
Page 265.

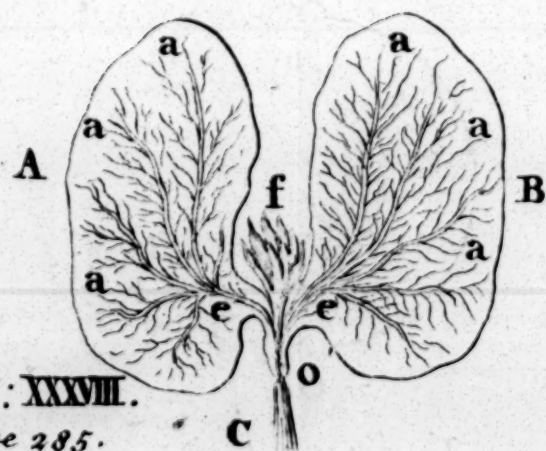
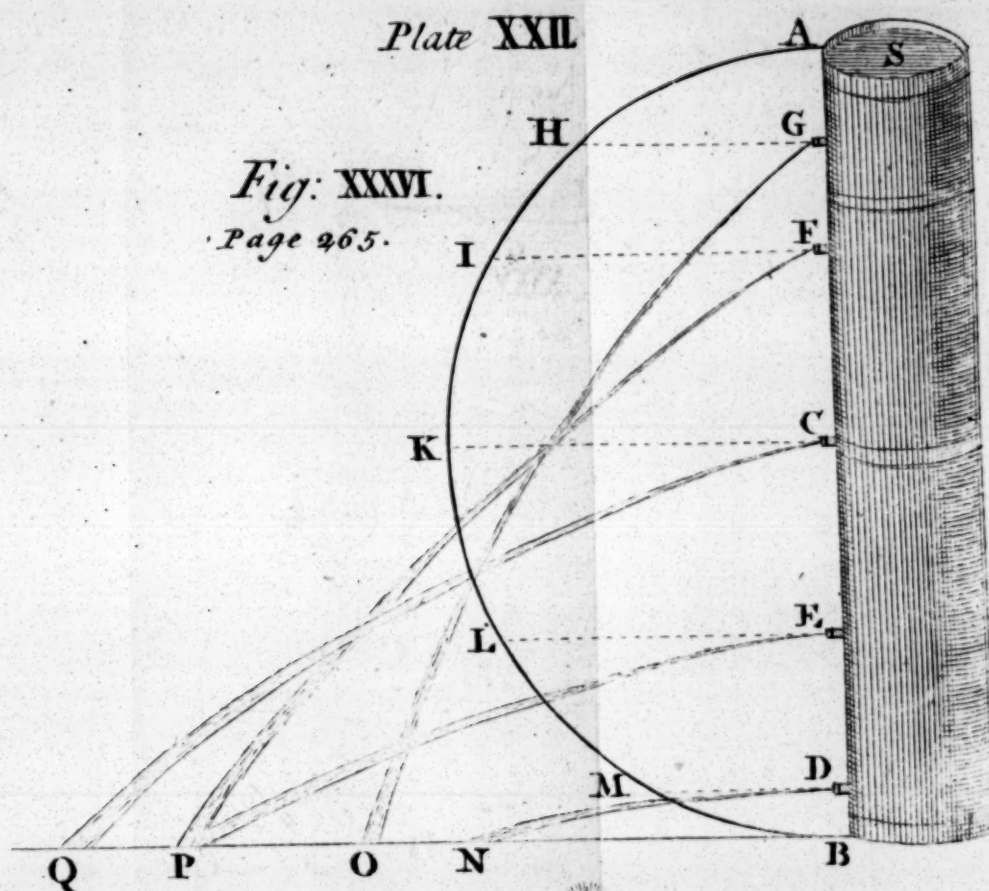
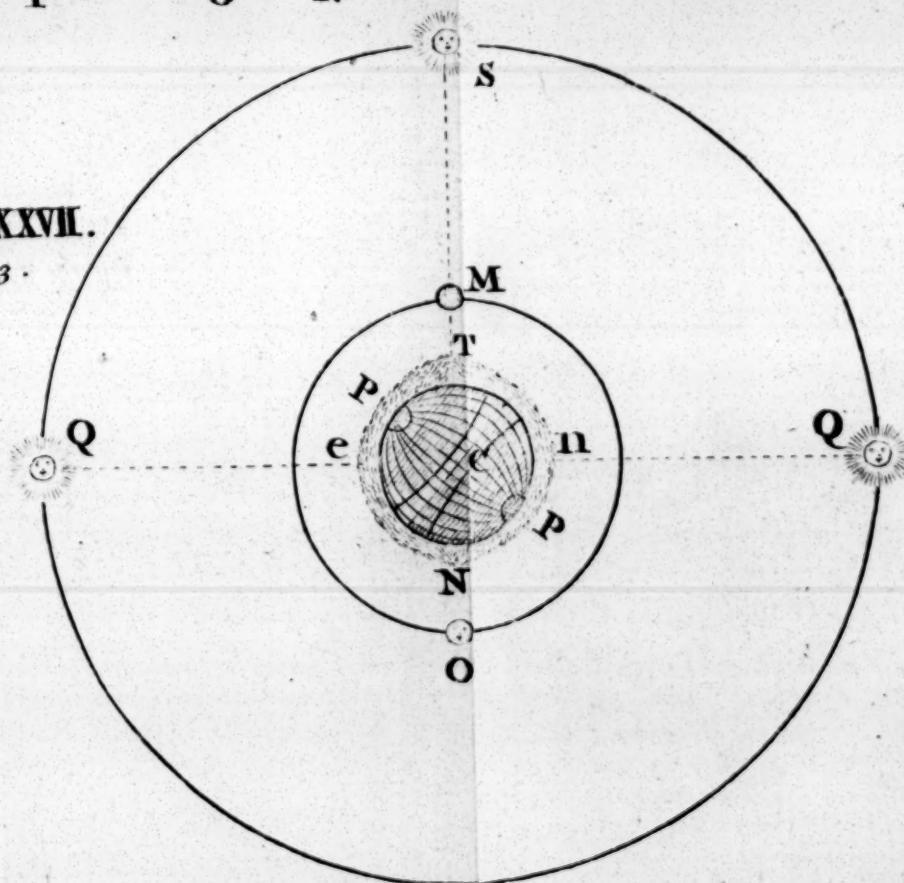


Fig. XXXVIII.  
Page 285.

Fig. XXXVII.  
Page 273.









# An ESTIMATE of the specific Gravity of SOLIDS.

| In Air 60 Grains.           | In Wat. | Dim.            | Prop.           |
|-----------------------------|---------|-----------------|-----------------|
| Crude Mercury               | —       | $4\frac{1}{2}$  | 14              |
| Lead                        | —       | $5\frac{1}{4}$  | 11              |
| Copper                      | —       | 7               | 8               |
| Brass                       | —       | 7               | 8               |
| Crude Tin                   | —       | 7               | 8               |
| Regulus of Antimony         | —       | 8               | $7\frac{1}{2}$  |
| Regulus of Steel and Copper | —       | 8               | $7\frac{1}{2}$  |
| Block Tin                   | —       | 8               | $7\frac{1}{2}$  |
| Iron                        | —       | 8               | 7 fere          |
| Cinnabar of Antimony        | —       | $8\frac{1}{2}$  | 7               |
| Litharge of Silver          | —       | 9               | $6\frac{1}{2}$  |
| Litharge of Gold            | —       | 9               | $6\frac{1}{2}$  |
| Silver Sixpence             | —       | $9\frac{1}{2}$  | 6               |
| Calcined Copper             | —       | 11              | $5\frac{1}{2}$  |
| Glass of Antimony           | —       | 11              | $5\frac{1}{2}$  |
| Lapis Calaminaris           | —       | 12              | 5               |
| Tutty                       | —       | 12              | 5               |
| Crocus Metallorum           | —       | 13              | $5\frac{8}{13}$ |
| Crude Antimony              | —       | $13\frac{1}{2}$ | $4\frac{1}{2}$  |
| Prepared Steel              | —       | 15              | 4               |
| White Lead                  | —       | 19              | $3\frac{1}{9}$  |
| Green Glass                 | —       | 19              | $3\frac{1}{9}$  |
| Red Coral                   | —       | 21              | $2\frac{1}{2}$  |
| Flint                       | —       | 21              | $2\frac{1}{2}$  |
| Bole Armoniac               | —       | 22              | $2\frac{1}{2}$  |
| Lapis Judaicus              | —       | 22              | $2\frac{1}{2}$  |
| Flint Glass                 | —       | $21\frac{8}{9}$ | $2\frac{1}{2}$  |
| Bone of a Sheep just killed | —       | $21\frac{7}{8}$ | $2\frac{1}{2}$  |
| Filings of Steel            | —       | 27              | 2               |
| Lemnian Earth               | —       | 30              | 2               |
| Ivory                       | —       | 30              | $1\frac{1}{2}$  |
| Hartshorn                   | —       | 31              | $1\frac{1}{2}$  |
| Mineral Sulphur             | —       | 32              | $1\frac{1}{2}$  |
| Crude Tartar                | —       | 32              | $1\frac{1}{2}$  |
| Venice Glass                | —       | 33              | 0               |
| Ruff of Brass               | —       | $33\frac{1}{2}$ | $1\frac{1}{2}$  |
| Burnt Lead                  | —       | 35              | $1\frac{1}{2}$  |
| Gum Arabic                  | —       | 36              | $1\frac{1}{2}$  |
| Opium                       | —       | 42              | $12\frac{2}{3}$ |
| Lignum Guaiacum             | —       | 44              | $1\frac{1}{4}$  |
| Gum Tragacanth              | —       | 45              | $1\frac{1}{4}$  |
| Myrrh                       | —       | 45              | $1\frac{1}{4}$  |
| Gum Guaiacum                | —       | 48              | $1\frac{1}{4}$  |
| Refin of Scammony           | —       | 49              | $1\frac{1}{4}$  |
| Lignum Nephriticum          | —       | 50              | $1\frac{1}{4}$  |
| Isinglass                   | —       | 50              | $1\frac{1}{4}$  |
| China Root                  | —       | 54              | $1\frac{1}{4}$  |
| Frankincense                | —       | 56              | $1\frac{1}{4}$  |
| Gall                        | —       | 58              | $1\frac{1}{4}$  |
| Gentian                     | —       | 0               | $0\frac{1}{2}$  |
| Peruvian Bark               | —       | 0               | $0\frac{1}{2}$  |
| Oak                         | —       | 0               | $0\frac{1}{2}$  |
| Fir                         | —       | 0               | $0\frac{1}{2}$  |

# (Page 263.) An ESTIMATE of the specific Gravity of LIQUIDS.

| The Weight of a Piece of Lead in the several Fluids here below.           | Weight.          | Dim.            | Prop.           |
|---------------------------------------------------------------------------|------------------|-----------------|-----------------|
| In Air                                                                    | —                | 0               | 0               |
| Oil of Vitriol                                                            | 455              | 76              | $5\frac{7}{8}$  |
| Herm. Spirit of Nitre                                                     | 379              | 72              | $5\frac{1}{2}$  |
| Spirit of Nitre, with Oil of Vitriol                                      | 383              | 59              | $7\frac{1}{2}$  |
| Spirit of common Nitre                                                    | 396              | 58              | $7\frac{1}{2}$  |
| Spirit of Nitre Bezoartic                                                 | 397              | 58              | $7\frac{1}{2}$  |
| Double Aquafortis                                                         | 400              | 55              | $8\frac{1}{2}$  |
| Spirit of Vitriol                                                         | 406              | 49              | $9\frac{1}{4}$  |
| Spirit of Salt, with Oil of Vitriol                                       | 408              | 47              | $9\frac{1}{4}$  |
| Solution of common Salt                                                   | 408              | 47              | $9\frac{1}{4}$  |
| Simple Aquafortis                                                         | 410              | 45              | $10\frac{1}{2}$ |
| Spirit of Sal. Armon. Succ.                                               | 409              | 46              | $9\frac{1}{4}$  |
| Solution of Sal. Enix. 1 oz. in Water 5 oz.                               | 410              | 45              | $10\frac{1}{2}$ |
| Decoction of Gentian                                                      | $410\frac{1}{2}$ | $44\frac{1}{2}$ | $10\frac{1}{2}$ |
| Spirit of Tartar                                                          | 411              | 44              | $10\frac{1}{4}$ |
| Decoction of Snakeweed                                                    | 411              | 44              | $10\frac{1}{4}$ |
| Spirit of Hartshorn not rectified                                         | 411              | 44              | $10\frac{1}{4}$ |
| Decoction of Sarfaparilla                                                 | 412              | 43              | $10\frac{1}{2}$ |
| Decoction of China Root                                                   | 412              | 43              | $10\frac{1}{2}$ |
| Spirit of common Salt                                                     | $412\frac{1}{2}$ | $42\frac{1}{2}$ | $10\frac{1}{2}$ |
| Decoction of Arum                                                         | $412\frac{1}{2}$ | $42\frac{1}{2}$ | $10\frac{1}{2}$ |
| Solution of Arum 1 oz. 1 dr. in Water 6 oz.                               | 413              | 42              | $10\frac{1}{2}$ |
| Syden. Liquid. Lauden.                                                    | 413              | 42              | $10\frac{1}{2}$ |
| Liqu. Panacea of Opium                                                    | 413              | 42              | $10\frac{1}{2}$ |
| Decoction of Peruvian Bark                                                | 413              | 42              | $10\frac{1}{2}$ |
| Decoction of Pomegranates                                                 | 413              | 42              | $10\frac{1}{2}$ |
| Solution of Sal Armon. pur. 1 oz. and white Vitriol. 1 oz. in Water 5 oz. | 413              | 42              | $10\frac{1}{2}$ |
| Urine                                                                     | —                | $41\frac{1}{2}$ | 11              |
| Sweet Spirit of Nitre                                                     | $413\frac{1}{2}$ | $41\frac{1}{2}$ | $11\frac{1}{2}$ |
| Common Water                                                              | 414              | 41              | $11\frac{1}{2}$ |
| Tincture of Alum, with Water                                              | 414              | 41              | $11\frac{1}{2}$ |
| Decoction of Red Saunders                                                 | 414              | 41              | $11\frac{1}{2}$ |
| Distilled Vinegar                                                         | 414              | 41              | $11\frac{1}{2}$ |
| Mint, Rue, Savin Water, distilled                                         | $414\frac{1}{2}$ | $40\frac{1}{2}$ | 0               |
| Vinegar                                                                   | 415              | 40              | $11\frac{1}{2}$ |
| Milk                                                                      | $415\frac{1}{4}$ | $39\frac{1}{2}$ | $11\frac{1}{2}$ |
| Infusion of Horehound                                                     | $415\frac{1}{2}$ | $39\frac{1}{2}$ | $11\frac{1}{2}$ |
| — of Mint and Wormwood                                                    | 416              | 39              | $11\frac{1}{2}$ |
| Elix. prop. with Sal Volat.                                               | 416              | 39              | $11\frac{1}{2}$ |
| Infusion of Tea                                                           | $416\frac{1}{2}$ | $38\frac{1}{2}$ | $11\frac{1}{2}$ |
| Spirit of Saffron                                                         | $416\frac{1}{2}$ | $38\frac{1}{2}$ | $11\frac{1}{2}$ |
| Sweet Spirit of Salt                                                      | 417              | 38              | 12              |
| Tincture of Castor                                                        | $418\frac{1}{2}$ | $36\frac{1}{2}$ | 12              |
| Spirit of Wine Camph.                                                     | 419              | 36              | 12              |
| Myns. Tincture of Steel                                                   | 419              | 36              | 12              |
| Tincture of Sulphur, with Spirit of Turpentine                            | 420              | 35              | 13              |
| Oil of Turnips                                                            | 420              | 35              | 13              |
| Tincture of Coral                                                         | 420              | 34              | $13\frac{1}{2}$ |
| Spirit of Wine                                                            | $421\frac{1}{2}$ | $33\frac{1}{2}$ | $13\frac{1}{2}$ |
| Oil of Turpentine                                                         | $422\frac{1}{2}$ | $32\frac{1}{2}$ | $13\frac{1}{2}$ |
| Spirit of Wine rectified                                                  | $423\frac{1}{2}$ | 32              | 14              |
| Boiled Water                                                              | 424              | 31              | $14\frac{1}{2}$ |



them separately in Water, you find their Weights therein to be  $54\frac{1}{4}$  and 29 ; now the Deficiency of these Weights are 5 , and 31. Therefore the Ratio or Proportion of the Weight of Lead to that of Ivory, is as 31 to  $5\frac{3}{4}$ ; that is, Lead is almost  $5\frac{2}{3}$  Times heavier than Ivory.

A. Sir, I perfectly apprehend you now, and thank you ; pray do you estimate the specific Gravities of Liquids after the same Manner ?

B. They are estimated thus : Take a Piece of Lead, which suppose to weigh 455 Grains ; then the same weighed in Oil of Vitriol will be found no more than 379, and in common Water 414 Grains. The Diminution in the first Case is 76, in the latter 41 Grains ; these Numbers are inversly as the specific Gravities. Wherefore the Gravity of *common Water* is to the *Oil of Vitriol*, as 76 to 41 ; that is, almost as heavy again. Do you understand me ?

A. Yes, Sir, very well : I only wish I had such a Pair of Scales as are fit for this Purpose ; for then I should take a deal of Pleasure in making those Kinds of Experiments.

B. Sir, you may easily obtain a Pair ; and till then, I can lend you a *Synopsis* of an Estimate of the *specific Gravity* of *various Solids and Liquids*, which I have taken from Dr. Quincy, if you think it worth your Perusal \*. A. Sir,

\*1. The best Method that I can find for discovering the *specific Gravity of Solids and Fluids*, with Ease, Expedition, and Certainty, is by means of a fine *Hydrostatic Stee yard* and *Sliding Rule*.

2. The Steelyard is thus cheaply and easily made: Take the Beam of a fine Pair of Scales, as AO (*Fig. LXIII. on Plate XX, fronting p. 233.*) let the Smith make the Arm CO of a sufficient Length CB, by joining a small Iron Rod thereto ; to the End of



*A. Sir*, I am very much obliged to you for so extraordinary and useful a Piece of philosophical

the other Arm at A fix a Ball of Lead, or Tin, &c. D, such that its Weight, together with that of the Arm AC, may exactly balance or equipoise the Weight of the other lengthened Arm CB.

3. The Arm CB being duly shaped, is to be graduated after this manner: Suspend two equal Balls or Weights, E and F, one on each Side the Point C, at equal Distances, CA, CO, they there abide *in Equilibrio*; therefore O is the Point from whence the Degrees are to begin. If now you add 10 Weight of 10 Grains to the Ball F, and move the other from O a little towards B, you will find the Point 10 where the Weights will be exactly *in Equilibrio*. If you add 10 more Grains to F, the Ball E being again moved towards B, will give the Point 20, where it will equibalance the other. And thus by adding 10 Grains constantly to F, you will gain the Points of Division in the other Arm for every 10 Grains to an 100, or any greater Number; all which is evident from the Figure.

4. The *Steelyard* being thus graduated, a fine Thread of Silk (whose Weight is inconsiderable) is to be fixed to the Ball F with a Loop at the lower End, in which any Body, or Piece of Matter, may be put as at one, and then weighed by moving the Wire of the Ball E over the Degrees, as in the common *Steelyard*, till it comes to an Equilibrium; then the Body is to be suspended and weighed in a Vessel of Water, as GH; and then the Difference of its Weight *in* and *out* of the Water will be with Ease obtained, be the *Figure* or *Weight* of the Body what it will, within the Compass of the Instrument.

5. When, by this Means, you know what any given Number of Grains lose being weighed in Water, it is easy by the Sliding Rule to find what an 100 Grains will lose. Thus if 60 Grains of Lead lose  $5\frac{3}{4}$ , an 100 will lose  $9\frac{3}{4}$  nearly; and thus a Table of the *specific Gravities* of *Solids* and *Fluids* may be constructed with the greatest Expedition. By this *Steelyard* I have examined many of the Gravities I have here given in the Table, and find they are very true.

6. But since *Gold* is not among the other Solids, I thought it would not be amiss if I here subjoin a small Table of the specific Gravity of Gold and the other Metals, with Air and Water, in one View.

|             |       |       |                |
|-------------|-------|-------|----------------|
| Gold        | 19636 | Iron  | 7852           |
| Quicksilver | 14019 | Tin   | 7321           |
| Lead —      | 11345 | Stone | 2000           |
| Silver      | 10535 | Water | 1000           |
| Copper      | 8843  | Air   | $1\frac{3}{7}$ |

Curiosity;

Curiosity: And, pray, have you nothing very remarkable to be observed from the foregoing Laws of the Pressure of *Fluids*?

B. Yes, more than I can here exemplify to you; however, that you may know something of them, learn their Use in the following Instance: Suppose AB (*Fig. XXXVI. on Plate XXII, fronting p. 262.*) a Cistern or Tube filled with Water always even to the Brim, as at S; now let there be any Number of Holes DECFG made through the same, the Water spouting through each of them, will fall to an horizontal Distance, which is double to the Distances of those Holes from the Periphery of a Circle AKB, described about the Length of the Tube as a Diameter \*.

A. If this be the Case, I easily perceive why, in the Scheme, the Water spouting from the middle Hole C, falls farthest from the Tube; for, according to you, the Distance BQ, to which it falls, is equal to twice CK, that is, equal to the Height of the Tube AB; and as this CK is the farthest Distance from the Circle, the Double thereof BQ must needs be greater than the Double of any other Distance, and therefore its Water spouts the farthest.

B. You take the Reason of the Thing very well; you may also farther observe, that from two Holes EF, equally distant above and below the central Hole C, the Water will spout to an equal Distance BP, the Double of EL or FI, which are equal Distances from the Circle: Also

\* Dr. *Gravesande* proves the Truth of this in his *Elements*, Book I. Chap. 24. p. 101, 102, 103. And Book II. Part 2. Chap. 7, 8, 9, are wholly on these Subjects.

the Water from G will spout to O, which is double the Distance GH; and the Water from D will spout to N; for BN is double the Distance DM from the Circle.

A. I understand you thoroughly concerning this; have you any thing else to observe of the Pressure of *Fluids*, pray?

B. One Thing amongst many I could name is this: That, let a Body be ever so heavy, yet it may be made to swim in Liquids.

A. This is very surprizing indeed! What, can *Lead* or *Gold* be made to swim in Water, Sir?

B. Yes, by knowing their specific Gravities: Thus, because the specific Gravity of Gold is to that of Water, as 19 to 1; therefore if you hold a Guinea to the Bottom of a Tube of equal Diameter (so as no Water can get in) by Means of a String; then put the Tube down in the Water above 19 Times the Thickness of the Guinea in Depth, and letting the String go, the Guinea will not sink, but ride sustained by the Pressure of the subadjacent Water, which now is stronger than the Power of Gravity in the Guinea; and thus you may make any Body swim, how large, solid, and weighty soever\*.

A. Well,

\*1. The Writers on Hydrostatics demonstrate, that the Pressure of Liquids on the Bottom and Sides of Vessels is always proportional to the Height thereof, and every Way equal at the same Depth.

2. To illustrate this, let GE (*Fig. LXIV. on Plate XX, fronting Page 233.*) be a Vessel, from whose upper Part HE proceeds a tall Tube ABCD communicating therewith. Let this Tube and Vessel be filled with Water, then shall the Pressure of the Water on the Bottom GF be as great, and every Way the same, as it would be, were the Vessel itself as high as the Tube, and filled with Water to the Level of PS; that is, the Column of Water ANCB in the present Case has the same Effect on the Bottom of the Vessel GE, as the Column of Water PGFS would have.

3. This is no small *Paradox*, but is notwithstanding that very easy to conceive; for since Fluids act in every Direction, or press every



A. Well, I thank you for these general Instructions concerning the Nature and Effects of Fluids: And now, Sir, if you please, we will direct our Discourse to the Contemplation of

every Way, and every Way equally, and *Action* and *Reaction* is equal, and contrary; it must follow, that the Parts of the Bottom LN and GL (being equal to NO) will sustain the same Pressure as NO, or as they would do, were the Columns of Water continued to the Height PQA. For in the Line CN, the Force of the Column of Water AO is exerted on each Side equally, and has the same Effect at IL as at DO, and therefore the lateral Pressure being equal, the perpendicular Pressures also on LN and NO will be equal.

4. Or thus: If the Pressure on the Part IL were less than on the Part DO, the Fluid in the Column CO would, by reason of its greater Gravity, have a Motion toward the Part IL, and the Surface AB would descend: But since there is a perfect Quiescence of all the Parts of the Fluid, and that in the Column CO is as much at Rest as that in the Column CL, it is evident their Pressures and Effects are every Way the same, and consequently that the Column CL presses as much on the Part LN, as the Column CO does on the Part NO. What is thus proved of the Column IN, is to be proved of all the rest, HL, DM, and KF; which makes the Proposition manifest.

5. This *Paradox* is also easily proved by *Statics*; for suppose the Vessel fixed, and the Bottom GF moveable therein, and so adapted to it, that no Water should pass between it and the Sides of the Vessel; if this Bottom be hung to the Arm of a Balance by Means of a long Wire descending through the Tube, the Effect of the Water in the Tube may be compared with that in the Vessel, in regard of Weight. Thus suppose the Water in the Vessel to weigh one Pound, then admit the Height of the Tube AC be four Times the Height of the Vessel CN, if the Tube be filled with Water to AB, you'll find four Pounds must be added to the other one in the Scale to make an *Equilibrium*.

6. Or otherwise thus: Let the upper Part of the Vessel HE be connected with the lower Part or Bottom GF by Means of Leather, in the Manner of a Pair of *Bellows*; then, if the Tube AD be fixed into the upper Part, and Water poured therein, it will raise the upper Part from the Bottom charged with Weights equal to the Weight of a Column of Water equal to PGFS.

7. I have been the more particular on this wonderful Property of Fluids, because it is not only in itself very curious, but of great Importance in many Affairs of Life; and they who would see more, may consult the Authors above referred to, especially Dr. *Gravesande's Elements*.

Water

Water in particular; and first we will begin with the Waters of the Sea: What therefore do you find is known concerning their Extent, or what Proportion do the Superficies of the Sea bear to those of the dry Land?

*B.* This is not precisely known: I remember I once calculated the Proportion of Water and Land, as they are represented on my terrestrial Globe of 16 Inches Diameter, and found it to be somewhat more than  $\frac{2}{3}$ , but how much I cannot justly say, having lost my Notes of that Particular at present.

*A.* Pray how came the Earth to be covered over, so far the greater Part, by Water?

*B.* Thus it pleased God in the Beginning to order it; for wise Ends no doubt: The Waters of the Earth must necessarily rise to the Surface thereof, as being specifically lighter than Earth; and then it was as necessary there should be large Cavities therein for Receptacles to contain them, otherwise they would equally have overspread all the Superficies of the Earth, and so have rendered it utterly uninhabitable to Mankind\*.

*A.* I understand the Figure of the whole Earth is round, and consequently the Superficies of the Sea must be so too, which I think

\* On this Head hear the philosophical Poet *Ovid*:

The Earth of closer and compacter State,  
Fell self-incumber'd with her proper Weight;  
On her the grosser Elements attend,  
And to the deepest, lowest Part descend.  
The Waters last took Place, and flowing round,  
The girded Globe's extensive Circle bound.

*Metamorph. Lib. I. Scævell.*

you

you impute to the Action of Gravity or Power of Attraction in the Earth, do you not, *Sir*?

B. Yes, the Center of the Earth being the common Center of Gravity, and the Nature of Fluids being such, that they equally yield to equal Powers, and the Power of Attraction being every where equal at equal Distances from the Center, it follows, that the superficial Parts of Water will every where conform themselves to an equi-distant Situation from the Center, and consequently will form the Surface of a Sphere so far as they extend\*.

A. Pray, *Sir*, is the Sea higher than the Earth, or Land, as it seems to be?

B. No; for by the Power of Gravity all Things conform to a spherical Surface, in which no one Part is higher than another; besides, Fluids press every Part equally, and therefore would soon overflow the Shores, were they really lowest.

A. How comes it to appear so, then?

\* Thus *Ovid* again in the same Place:

Whatever God thus broke the formless Heap,  
And bid the Parts a just Proportion keep:  
First, that the Earth might regular appear,  
He rounds the Figure to a perfect Sphere, &c.

But herein the Poet is mistaken; for the Figure of the Earth is not that of a perfect Sphere, but an oblate Spheroid, whose longest Diameter is that of the Equator, and the shortest, that from Pole to Pole, the Difference being about  $34\frac{2}{5}$  Miles, according to Sir *Isaac Newton*, in his *Principia*, Lib. III. Prop. 19. p. 415. See also Dr. *Keill's* Examination of Dr. *Burnet's* Theory of the Earth, Chap. 6. And a large Dissertation on the Figure of the Earth by Dr. *Desaguliers*, in *Philosoph. Trans.* N<sup>o</sup> 316 to 389.

B. This



*B.* This results from the *Fallacy of Vision*, whereby all Objects, and the Parts of Land as well as Sea, the farther they are from us, the higher they appear: Thus in Pieces of Perspective, the Parts are all placed higher above the Ground Line, as they are situated more remote. The Reason of all which is easy from *Optics* \*.

*A.* Is the Depth of the Sea known?

*B.* *Varenius* affirms, the Depth or Profundity of the Sea is in some Places unfathomable; and in other Places is very various, being in some Places  $\frac{1}{2}$ ,  $\frac{1}{3}$ ,  $\frac{4}{10}$ ,  $1\frac{1}{10}$ ,  $2\frac{2}{10}$ ,  $4\frac{1}{2}$  *English* Miles, in other Places deeper, and is much less in Bays than in Oceans. The *Depths* of the *Sea* bear

\* It is well known, that the *denser* any Medium is thro' which we behold Objects, the greater is the *Refraction*, or the more their Images appear elevated above the Horizontal Level; also the greater Quantity of the Medium the Rays pass through; the more they will be bent from their first Direction; on both these Accounts the Appearance of Things remote, and on the Sea, will be somewhat above the Horizon; and the more so, as they are more remote.

2. The Sight, with regard to distant Things, is terminated with a spherical Superficies, of which the Eye is the Center, and therefore the more remote Things are, the higher they appear in this Superficies. For Instance, let the Eye be at G viewing the distant Surface of the Sea AE; and suppose AF be Part of the spherical Superficies which terminates the Sight: Let A, B, C, D, E be several Parts of the Sea's Surface, these will appear in the Sphere of Vision, at *a, b, c, d, e*, all above the horizontal Level HE; and every Part higher as it is more remote. See *Fig. LXV. on Plate XX, fronting p. 233.*

3. Nor is this the only Fallacy; but, if we suppose the Parts AB, BC, CD, and DE all equal to each other, they will appear very unequal to the Eye at G in the Sphere AF, that which is nearest being still the greatest; and the more remote the lesser. Again, if *ab, bc, cd, and de* be supposed equal, the Distance on the Sea will appear to be equal, tho' they are really very unequal; and, in this Case, the more remote, the larger. See much more to this Purpose in *Varenius's Geog. Gen. Book I. Chap. 13. throughout, but especially Prop. 1st and 2d thereof.*

great

great Analogy to the *Height of Mountains* on the Land, fo far as is hitherto difcovered.

*A.* Are you able to fay whence the Saltnefs of the Sea doth arife ?

*B.* It is very rationally judged to arife from great Multitudes both of Mines and Mountains of Salt, difperfed here and there in the Depths of the Sea : The Salt being continually diluted and diffolved by the Waters, the Sea becomes impregnated with its Particles throughout ; and for this Reason, the Saltnefs of the Sea can never be diminished \*.

*A.* Pray what is the Ufe of this falt Property of the Sea ?

*B.* The *Saltnefs* of the *Sea* preserves its Waters pure and fweet, which otherwife would corrupt and ftink like a filthy Lake ; and confequently none of the Myriads of Creatures which now live therein, could then have Being : From hence alfo the Sea Water becomes much heavier ; and therefore Ships of greater Size and Quantity may be ufed thereon. Salt Water alfo

\* *Dr. Halley* fupposes, that it is probable the greateft Part of the Salt of the *Sea*, and of all *Salt Lakes*, (as in the *Caspian Sea*, the *Dead Sea*, the *Lake of Mexico*, the *Titicaca* in *Peru*) is derived from the Water of the Rivers which they received ; and fince this Sort of Lakes has no *Exit* or *Discharge*, but by the Exhalation of Vapours, and alfo fince thefe Vapours are entirely fresh or devoid of Salt Particles, it is certain the Saltnefs of the Sea and fuch Lakes muft from Time to Time increafe ; and therefore the Saltnefs at this Time is greater than at any Time heretofore. He farther adds, that if, by Experiments made in different Ages, we could find the different Quantities of Salt which the fame Quantity of Water (taken up in the fame Place, and in all other the fame Circumftances) would afford, it would be eafy from thence, by the Rules of Proportion, to find the *Age of the World* very nearly ; at leaft, to destroy the Notion of the *Eternity of all Things*. *Philof. Trans.* N<sup>o</sup> 344.

doth not freeze so soon as fresh Water, whence the Seas are more free for Navigation.

*A.* I remember *Solomon* observes, that tho' all the Rivers run into the Sea, yet the Sea is not full, or doth not increase; pray is there any assignable Reason for this?

*B.* Yes; there are two Reasons why the Sea doth not increase. 1. Because Waters return from the Sea by subterranean Cavities and Aqueducts, through various Parts of the Earth. 2. Because the Quantities of Vapours raised from the Sea, and falling on the Land, only cause a Circulation, but no Increase of Water. It hath been found by Calculation, that in a *Summer's* Day there may be raised in Vapours from the *Mediterranean* 5280000000, or 5280 Millions of Tuns of Water, yet this Sea receiveth not from all its nine great Rivers above 1827000000, or 1827 Millions of Tuns *per* Day, which is but a third Part of what is exhausted in Vapours; wherefore we may rather wonder the Sea is not lessened than increased\*.

*A.* I am very much pleased with these Accounts of the *general Properties* of the Sea: But, pray, what do you say to that most obvious and wonderful *Phænomenon*, the Tide, or *Flux* and *Reflux* of the Sea?

\* See the Calculation at large in *Philos. Transf.* N<sup>o</sup> 212. or in *Joan. Clerici Physica*, Lib. II. Cap. 8. It has been found, that in the Years 1699, 1700, 1701, 1702, there fell at *Townley* in *Lancashire*, at the Foot of the Mountains,  $39\frac{3}{8}$ , 43,  $41\frac{2}{5}$ ,  $51\frac{5}{8}$  Inches of Water in Depth; and at *Upminster* in *Essex*, these Depths were, for the same Years,  $15\frac{1}{8}$ , 19,  $18\frac{7}{10}$ ,  $20\frac{4}{10}$  Inches. But *Dr. Halley* found that the Depth of the Water evaporated in a close Room in one Year was but eight Inches; from whence it is plain how much the Sun and Wind contribute to the Evaporation of Water.



B. It is now very well known, that the Tides are caused by the Attraction of the Moon, and are sometimes increased by the Attraction of the Sun conspiring therewith, as in Conjunctions, or new Moons, and those we call *Spring-Tides*; sometimes the Sun's Attraction acts counter to the Moon's, as in the Quadratures, and then the Tides are lessened, and are what we call *Neap-Tides*.

A. Pray be so good as to illustrate the *Doctrine of the Tides* by a Scheme.

B. I will. Suppose then C be the Earth, *Fig. XXXVII.* on *Plate XXII*, fronting *p. 262*, surrounded by Water PTN, M the Moon in Conjunction with, and O in Opposition to the Sun in S, and in her Quadratures from the Sun in Q: Now it is plain the Part of the Ocean T, to which the Moon M is perpendicular, will gravitate to the Moon more than any other Parts in the *Hemisphere eTn*; and therefore the Water in that Part will become lighter than usual, and so will tumify and rise up towards the Moon. On the contrary, the Water in N, being most remote from the Moon M, will be less attracted, or gravitate less towards the Moon, than any other Parts of the Land or Sea in the *Hemisphere eNn*; and therefore will keep at farthest Distance from the Moon, or, which is the same Thing, it becomes lighter than usual, and tumifies on the Part N, contrary to the Moon M. By this Means the Ocean must of Necessity conform itself to an oval Figure, whose longest Diameter is TN, and the shorter *en*: Now, because the Tides at T and N are existent both at the same Time,

S

and

and opposite to each other, it is evident, they following the daily Course of the Moon, that they must constantly succeed each other under every Meridian at the Distance of 12 Hours Time, and therefore twice each Day, as we see they do. Do you apprehend me so far?

*A.* Yes, very well; pray proceed.

*B.* Then the rest will be still easier: For suppose (as Sir *Isaac Newton* has) that the Attraction of the Sun be to that of the Moon at our Earth, as 1 to  $4\frac{4815}{100000}$ , or nearly, as 1 to  $4\frac{1}{2}$ ; that is, as 2 to 9. But Mr. *Domkey* has since made it to be as 1 to  $5\frac{10948}{100000}$ , or as 1 to 5, or more nearly still, as 10 to 51 (whose Numbers I shall use): I say, supposing this be the Proportion of the Sun and Moon's Power of attracting the Waters of our Seas, then it follows, that when the Sun and Moon are in Conjunction, the Waters at T and N will be attracted by both these Powers jointly; but, when the Moon is in Square to the Sun, that is, when those Luminaries are in M and Q, then the Power of the Sun in Q acts contrary to that of the Moon in M; and then the Waters in T and N are raised only by the Difference of those Powers; so that the *Spring-Tides* will be to the *Neap-Tides*, as the Sum to the Difference of those Powers; that is, as 6 to 4, or as 61 to 41. So that, if the Sun be able to raise the Water 1 Foot 11 Inches, the Moon will raise it above 9 Feet 7 Inches, and both together, about  $11\frac{1}{2}$  Feet, which is still greater, as the Moon is nearer the Earth.

*A.* Pray in what Parts of the Earth are the Tides greatest of all?

*B.* About

B. About the *Æquator* or Middle of the Earth : For the greater the Circle, in which the Tides revolve, the greater will be their Agitation ; and were the Moon placed in the Pole, the Tide would remain immoveable about that Pole.

A. Are the Tides always largest precisely at the Time of new and full Moons ?

B. No ; for by Reason of the Water's Libration, those Tides are somewhat changed, being greatest about three Tides later.

A. Are the same Tides (*viz. Spring or Neap*) in the same Place, all the Year round, equal ?

B. No ; for, as I shewed you a while ago, the Earth is something nearer the Sun in the *Winter* than in the *Summer* ; therefore the greatest Equinoctial Tides are observed to happen some Time before the vernal Equinox, and after the autumnal one.

A. Does the different Position of the Moon in her Orb make any Difference of the Tides ?

B. Yes ; because in the diurnal Revolution of the Moon, that Tide of the two ought to be greatest, in which the Moon is nearest to the *Zenith* or *Nadir* of the Place ; therefore with us, the Moon being nearest our *Zenith* in the *Northern* Signs, when above the Horizon, must then cause the greatest of the two Tides when she passeth our Meridian ; but being nearest the *Nadir*, when in the *Southern* Signs, she makes the greatest Tide here, when she passeth the opposite Meridian, below the Horizon \*.

A. Do

\* These, and all other Affections of the Tides arising from the different Latitudes of Places, will be easily and best understood by Fig. LXVI. on Plate XX, fronting p. 233. Where APE is the



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*A.* Do all these *Phænomena* of the Tides agree with Observations every where, or in all Parts of the Sea?

*B.* Very sufficiently in the main Oceans; but are more or less altered and interrupted in *Bays, Straits, Havens, &c.* where those general Causes cannot produce their Effects freely. And thus I have related to you all the general Affections of the Tides, which you may reduce to particular Cases yourself.

*A. Sir,* I am extremely obliged to you; pray tell me in the next Place whence *Fountains* and *Springs* may arise?

the Earth covered over with very deep Waters, *C* its Center, *Pp* its Poles, *AE* the Equinoctial, *Ff* the Latitude of a Place, *Dd* another at equal Distance on the other Side the Equinoctial, *H, h*, the two Points where the Moon is vertical, and let *Kk* be the great Circle wherein the Moon appears horizontal.

It is evident that a *Spheroid* described upon *Hh* and *Kk* shall nearly represent the Figure of the Sea; and *Cf*, *CD*, *CF* and *Cd*, shall be the Heights of the Sea in the Places *f*, *D*, *F*, *d*; in all which it is *High Water*: And seeing that in 12 Hours Time, by the diurnal Rotation of the Earth, the Point *F* is transferred to *f*, and *d* to *D*, the Height of the Sea *CF* will be that of *High Water* when the Moon is present, and *Cf* that of the other *High Water* when the Moon is under the Earth; which in the Case of this Figure is less than the former *CF*. For *CF* is near the greatest Semi-diameter of the Spheroid *CH*, and *Cf* is nearest the least *CK*.

And in the opposite Parallel, *Dd*, the contrary happens; the Rising of the Water being always alternately greater and less in each Place when it is produced by the Moon's declining sensibly from the Equinoctial, that being the greatest of the two *High Waters* in each diurnal Revolution of the Moon, wherein she approaches nearest either to the *Zenith* or *Nadir* of the Place. Consequently, the Moon in the Northern Signs in that Part of the World makes the greatest Tides when above the Earth, and in the Southern Signs when under the Earth; the Effect being always the greatest where the Moon is farthest from the *Horizon* either above or below it; and this alternate Increase and Decrease of the Tides has been observed to hold good on the Coast of *England*, at *Bristol* by Captain *Sturmy*, and at *Plymouth* by Captain *Colepreffe*. *Philos. Trans. N° 226.*

*B. Foun-*

B. *Fountains*, or *Springs*, are of two Sorts, viz. 1. Those which run in the *Winter*, and dry up in the *Summer*, called *temporal*: And, 2. Those which constantly keep running, called *perennial Springs*. *Temporal Springs* arise generally from great Rains which sink thro' the Surface of the Earth, and are collected in the Crevices, and subterraneous Veins and Channels, and several smaller ones uniting, form larger Courses, which tend, thro' various Windings and Declivities, to some Part of the Earth's Superficies, where they break thro' and discharge themselves in little Streams and Brooks. Those which are called *perennial*, are supposed to derive their Waters from the Ocean itself, by Ducts and hollow Passages running thence through the Bowels of the Earth to various Parts of its Superficies, where they discharge themselves, as do others. But many very learned Naturalists are of Opinion, that these are supplied with their Waters, if not wholly, yet chiefly, by *Rain*, as well as *temporal Springs*. The Learned are variously divided in their Judgments about the Original of *Springs*: However, this we know, that Lakes, Wells, and several Streams, and some great Rivers, owe their Original intirely to Springs; as also all Baths and Fountains, are only a Collection of Waters issuing from those *Springs* \*.

A. It

\* The great Number of those who hold that Springs are derived from the Sea, and of those who ascribe their Original to Rain and dissolved Snow, see in *Johnson's Quæst. Philosophicæ*, Cap. 2. Quæst. 34.

Dr. *Woodward* has an Hypothesis which makes the Origin of Fountains to consist in an Abyss of Waters in the Bowels of the

*A.* It is true, that I can see with my Eyes: But, pray, whence is it that their Waters have such vastly different Qualities?

*B.* From the Qualities and Temperament of the Soil or Earth through which those subterranean Waters pass. Thus those Waters which pass thro' Lays or Beds of metallic or mineral Earth, carry along with them some of those mineral Particles, and thence become endued with the Quality of those Metals and Minerals; and thus we call them *mineral Waters*, of which there are various Species, as *acid, bitter, hot, cold, oily or fat, coloured, boiling, petrifying, salt, &c.* which constitute various Kinds of Baths and Wells of medicinal Waters: Thus those Waters which boil up *hot*, are made so by subterranean Fires and Fumes of Sulphur, and other inflammable Substances. Those which are *salt*, contract their Saltiness from the Quantities of Salt they pass through in the Earth; and those which are *oily, &c.* from the sulphureous and bituminous Matter melted in the Bowels of the

Earth; which Water, he says, is made to ascend by Means of subterranean Fire. But Dr. *Arbuthnot* has refuted this Doctrine in his Examination of the Doctor's History.

All this Time the most plausible and commonly-received Hypothesis concerning the *Origin of Fountains*, is that of Dr. *Edmund Halley*, viz. *The Condensation and Precipitation of Vapours from the Tops of high Mountains by a cold and rarefied Air*; where, says he, the Water gleeting down by the Crannies of the Stone, Part thereof enters into the Caverns of the Hills, and gathers together as in an Alembic into the Basons of Stones it finds; which being once filled, all the Overplus runs over by the lowest Place, and breaking out by the Sides of the Hills, forms single Springs: Many of these running down by the Vallies, form *Rivulets* or *Brooks*; many of these uniting their Streams in the Valley, and gaining plain Ground, become less rapid, and form a *River*; and many of these being united in one common Channel, make such Streams as the *Rhine, the Rhone, the Danube, &c.* *Philos. Trans. N° 192.*  
Earth



Earth by Heat and Spirit; and so of the rest.  
Thus *Varenius*.

A. Pray, to conclude this Head, what do you think of the Original of Rivers?

B. Some of them rise, as I said, immediately from Springs themselves; others from the Conflux of many smaller Streams, Brooks and Rivulets, which together make one great Current or Stream. *Lastly*, Vast Defluxions of Rain, melted Snow, condensed Vapours, &c. from the Sides of high Mountains, tear up the Earth, and form the largest Channels and Rivers in the World, whose rapid Streams all run into the Sea in some Part or other.

C H A P. IV.

PHYTOGRAPHY, or the PHILOSOPHY of PLANTS and VEGETABLES, of VEGETATION, of their Production, of the SEED, and SEED PLANT of the ROOT, of the BLADE, STALK and TRUNK, of the BUD, LEAVES and FLOWERS, of the FRUIT, &c. of the PERSPIRATION of Plants, &c.

A. PLEASE, Sir, to explain to me the Word *Phytography*.

B. It is compounded of *φύτον*, a *Plant*, and *γραφὴν*, a *Description*; and thus it implies a *physiological Description of Plants*, and all Kinds of *Vegetables*.

A. Pray, Sir, what do you call *Vegetables*?

S 4

B. All

*B.* All such natural Bodies as grow and increase from Parts organically formed, or serving as Instruments to convey the Principles of vegetative Life; but have no proper Life or Sensation; such as Plants, Shrubs, and Trees.

*A.* Pray explain to me what you mean by *vegetative Life*, or *Vegetation*.

*B.* The Faculty or Quality which Plants are endued withal, whereby they attract Nourishment, or nutritious Juices from Earth, and which circulating their Substance, causeth it to extend, unravel, or unfold its Parts by Degrees, till at length every Part turns out in its proper Form and Site, and thus the Plant is perfected.

*A.* Do you say, that the vegetable Life and Growth of Plants and Trees proceed from the Juices of Earth, and not from the Earth itself?

*B.* Yes, and that is the Truth: For Mr. *Boyle* found by Experiment, that a Plant of three Pounds, and after that, a Plant of 14 Pounds, were produced from a Quantity of Earth, watered only with Rain or Spring Water, which lost scarce any Thing of their Weight, being precisely weighed dry, before and after the Production of the Plants.

*A.* Indeed, I cannot say but such an Experiment undeniably proves, that Plants receive their Growth and Weight from the Moisture of the Earth altogether, and not from the Substance of the Earth itself.

*B.* Yes, I can give a more convincing Instance yet: *Van Helmet* dried 200 lb. of Earth, and therein planted a Willow weighing 5 lb. which he watered with Rain or distilled Water; and

and to secure it from other Earth getting in, he covered it with a perforated Tin Cover : After five Years, weighing the Tree with all the Leaves it had borne in that Time, he found it to weigh 169 Pounds three Ounces, but the Earth to have lost only about two Ounces of its Weight \*.

A. Sir, I am fully convinced and satisfied of this Matter : But, pray, how is the first *Generation* or Production of Plants accounted for ?

B. All Plants and Vegetables are immediately produced and generated from some *Parent Plant*, or *Vegetable Seed*, of the same Species.

A. How can this be, when Plants have been often found to grow where Seeds were never sown, or could come ?

B. There may be a three-fold Answer given to your *Query* : For, 1. It is possible those Plants may spring from Seeds which may have lain hid in the Earth in those Places more than the Age of Man ; for some Seeds retain their Fecundity 40 or 50 Years. 2. They might rise from Seed waisted thither by the Wind, which by Reason of its wonderful Smallness could not be seen. 3. Those Seeds also might be brought thither in the Dung of Animals at first, and so increase. However, nothing can be more effectually confuted than the atheistical Doctrine of the *spontaneous Production*, or *equivocal Generation* of Plants or Animals, in the Works of modern Naturalists †. A. Well

\* See also Dr. Woodward's Experiments relating to this Matter, Philos. Transf. N<sup>o</sup> 253. Harris's Lexicon, under the Word *Vegetation* ; or in the *Philosophical Library*, under the Title *Botany*, Page 437.

† By the *spontaneous Production* of Plants is meant, their *growing*,



*A.* Well then, since you will have it that every *Plant* is produced from the *Seed* of a *Plant* of the same Species, be pleased to explain how this may be.

*B.* It is the Doctrine of modern *Physiologists*, that every *Seed* hath in itself what they call *Planta Seminalis*, or *Seed Plant*; that is, that the *Plant* which is produced from the *Seed*, is really and formally contained in the *Seed* (before it is sown) in *Miniature*; and when the *Seed* is sown, the *Parts* of the *Seed Plant*, now in *Embryo*, begin to vegetate, unfold, dilate, and at last burst the *Matrix Seed*, and so swell out of its native *Bed* of *Embryonism*.

ing, as it were, of their own Accord, or without *Seed*; and this in regard of *Animals* is called *Equivocal Generation*, whereby they are produced without Parents in *Coitu*.

That this Doctrine is directly *Atheistical*, is but too manifest; for supposing the Generation of some *Plants* and *Animals* to be spontaneous or casual now, we can't tell but that the Generation of all might have been so at first; and if the Being of any Thing be casual, or proceeding from *Chance*, it is certain all we can find in the Nature or Composition of such a Being, must also be fortuitous or by *Chance*. And thus all the Arguments derived from the wonderful Mechanism of the Whole, and the surprising Structure of the several Parts of *vegetable* and *animal Bodies* (the two great Magazines of Natural Religion) are utterly destroyed. But this is so notoriously contrary to common Sense and Reason, as to need no Refutation.

Indeed, to those who know not the Use of the Microscope, and have made no nice Enquiry into the Nature of Things, but consider every Thing in a rude and vulgar View, there may possibly appear some specious Arguments for *spontaneous Generation*; but they who are willing, may see them all confuted in *Bentley's Boyle's Lect. Sermon 4.* *Derham's Physico-Theol. Book IV. Chap. 15. Note (1.)* *Watt's Philos. Essays, Essay 9.* *Wolaston's Relig. of Nature, Page 88.* *Fr. Redi Exper. Nat. & de Gen. Insectorum.* *Ray's Wild. of God, Page 344.* *Clerici Phys. Part. IV. Cap. 2. § 33, & seqq.* *More's Antidote against Atheism, Book II. Chap. 6.* *Harris's Lexicon, at the Word Generation.* With the several Authors mentioned in *Johnson's Philos. Quæst. Page 26, 27, and 33, 34.*

A. Pray how came they by such a strange Notion of the Production of *Vegetables*?

B. By the Help of a *Microscope*; for thereby they have discovered and seen the involved *Stamen* of the future Plant in every single Seed, which is a very curious and delightful Spectacle indeed\*.

A. Why then, according to this new Doctrine, the first original Seed of each Kind (at the Creation) contained in it all the future Seeds and Plants, which were produced from it in all succeeding Ages; and yet itself no bigger then, than we see it now.

B. Yes, it did so indeed; and what is proved to be Fact, cannot be called in Question.

A. I cannot help questioning it: Is it possible, for Instance, that one of our white boiling Pease (which is capable of producing above an Hundred-fold each Year) should at the Time of the Creation contain within its small globular Bulk (about  $\frac{1}{4}$  of an Inch Diameter) all that yearly Product of Pease, Cods, and Haulm or Stalk, of that Kind ever since?

B. You know Matter doth consist of Parts, or Corpuscles, inconceivably small; and to raise your Admiration the higher, let us make the

\* By the *Stamen* is to be understood those Rudiments or simple original Parts of a Plant or Animal which first exist in the *Embryo* or *Fœtal State*, or in the *Seed*; and which afterwards, by Distinction and Accretion of nutritious Juices, extends itself to its utmost Bulk, and then the Plant or Animal is said to be perfectly formed, or arrived to its mature State. This, in Plants, is likewise called *Germen* or *Gem*, also *Plantule*, or small Plant; and may be seen in all Seeds with the Microscope, and in some with the naked Eye, as the Bean, and especially the Kidney-Bean, where the very Ribs of the Leaves of next Year's Plant are visible in the Seed of this.

following

following Calculation: Suppose in your own Case, that one white Pea will produce an 100 in the first Year; then those 100 will produce each an 100 more the second Year, and so in all 10000; these would produce in the third Year 1000000, in the fourth Year 100000000, in the fifth Year 10000000000, and so on, increasing each Year in a geometrical Proportion, whose common Ratio is 100; so that the Product in any Year will be expressed by a Number consisting of an Unit, with so many Cyphers annexed, as is equal to twice the Number expressing that Year; therefore supposing the Age of the World were 5673 Years this present Year, then all the Pease produced from that one Pea, to this Time, would require a Number, consisting of 11346 Places of Figures, to express them: But the Number of Pease (reckoning 50 to a Foot in Length) which would be contained in a Cube circumscribing the Orb of the Planet *Saturn* (which Orb is 1554000000 Miles in Diameter) would require no more than 44 Places of Figures to express them: The Quantity of Pease hitherto produced would equal such a Number of those immense Cubes, as would consist of 11303 Places of Figures, which is vastly beyond all Comparison and human Thought! Besides the far greater Quantity of Haulm, Cods, Roots, Leaves, &c.

*A.* Well, those who are blest with the Gift of Credulity to believe any Thing, may believe this; for my Part, I think it is the greatest Impossibility, that a small Pea should contain the Quantity of Matter before said, which is sufficient



cient to fill Millions of Millions of Millions of Worlds.

B. Then I find there is no making a modern modish Philosopher of you, *Sir*, in every Point?

A. No, I cannot but think in this Case they are some Way mistaken. I remember you told me, the Vulgar were often deceived by Vision without a Glass; and it is possible the Learned may be sometimes with one: But leaving this to the Inventors, pray what Kind of Process doth Nature take to raise the Plant from the Seed in the Ground?

B. The Method of Nature here (as in all her other Works) is most admirable, as will appear in the curious Mechanism and Construction of a Bean Root, for Instance; (see *Fig. XXXVIII. on Plate XXII, fronting p. 262.*) In that *Figure* AB represents the two Lobes of the Bean split, which are joined together by a little white Sprig in O; in each Lobe you see the Branches *aaa*, of that called the Seed Root *ee*, every where displayed thro' the Body of the Bean: These Branches of the Seed Root *ee* feed the little Sprout, or Earth Root *oc* (descending downwards) with the Pulp or Matter of the Bean (prepared by the Ferment of the Earth) till the said Earth Root is capable of penetrating the Earth, and extending its Parts sufficiently enough to extract, for itself and the Plant it is to sustain, Nourishment from the Juices and Moisture of the Earth: For from this Earth Root there springeth upward the Sprout F, called (by Dr. Grew) the *Pluma* or *Feather*; and in this *Pluma*, and the Earth Root together, is contained, in *Miniature*, all the future Plant.

A. Why

*A.* Why then it appears, that the Matter or Substance of the Bean serves much the same Purpose to the Seed Root, as the Yolk of an Egg to the Embryo Chick; or as the Earth doth afterwards to the Radicle, or Earth Root itself?

*B.* Yes, it doth so; and having enabled the Earth Root to shoot into the Earth, in order to procure its own Nourishment, it is then, by Means of the Seed Root, turned to the Use of the *Pluma*; causing it also to sprout upwards, in order to become a Trunk hereafter.

*A.* What becomes of those Seed Lobes AB, when the Earth Root no longer requires their Use?

*B.* They are, in most Seeds, carried upwards with the *Pluma* out of the Earth, after which they compose the *Seed Leaves*, as they are called, as in *Cucumbers* and *French Beans* we see them.

*A.* What is the Use of those *Seed Leaves* to Plants?

*B.* The Effects and Uses of these Seed Leaves (saith the learned *Malpighi*) are so necessary, that if they are pulled off, the Plant will not grow; or if it should any Way increase, it won't be compleat, but always defective. The Learned are divided as to their particular Uses to Plants.

*A.* In the next Place, please to let me know particularly in what Manner the Root of the Plant procures Nourishment for its Growth and Increase.

*B.* In order to this, I must shew you the Make and Construction of the Root, and, as it were, anatomize the several Parts to your View;  
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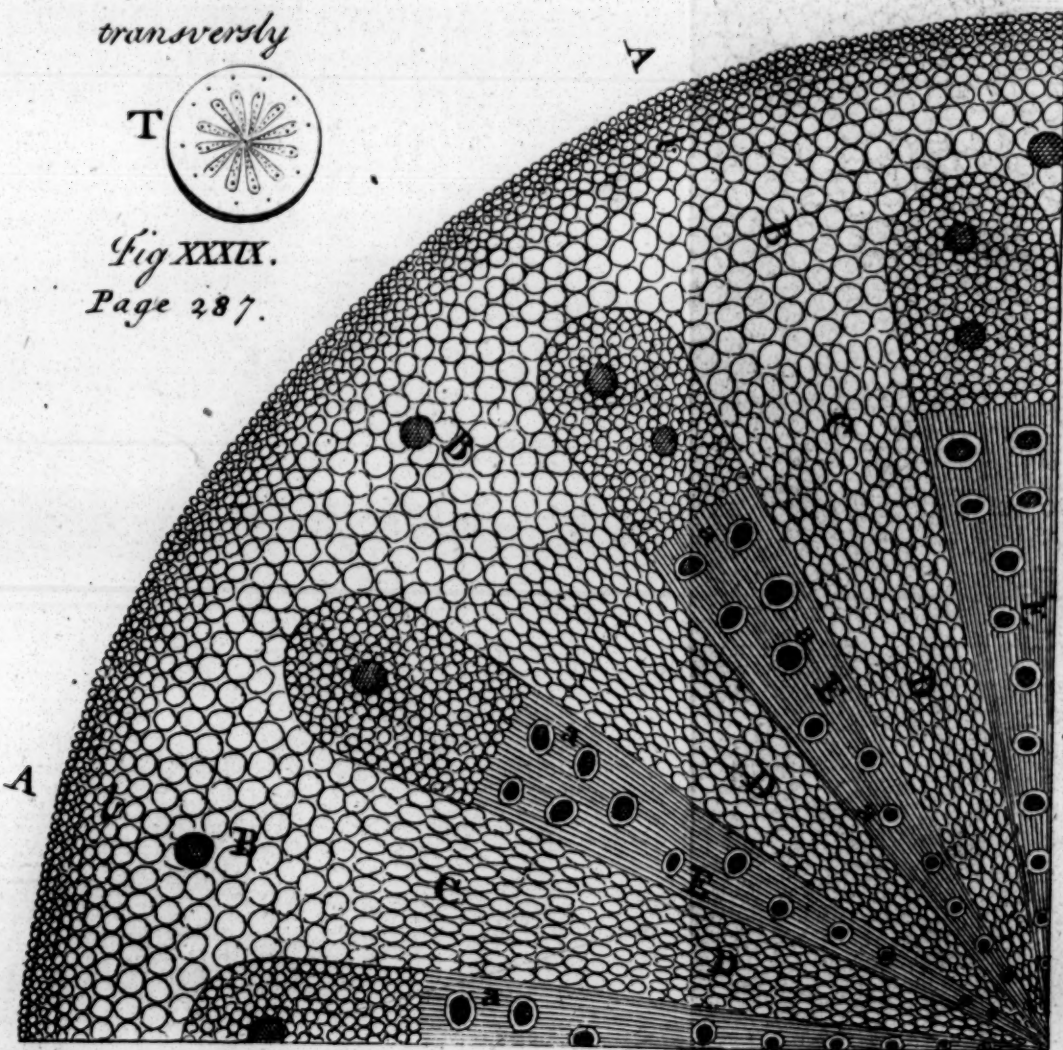


To front Page 287.

Wormwood Root cut  
transversely



Fig XXXIX.  
Page 287.



Magnify'd

Horse-Radish Root  
cut transversely

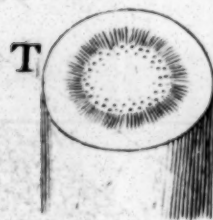
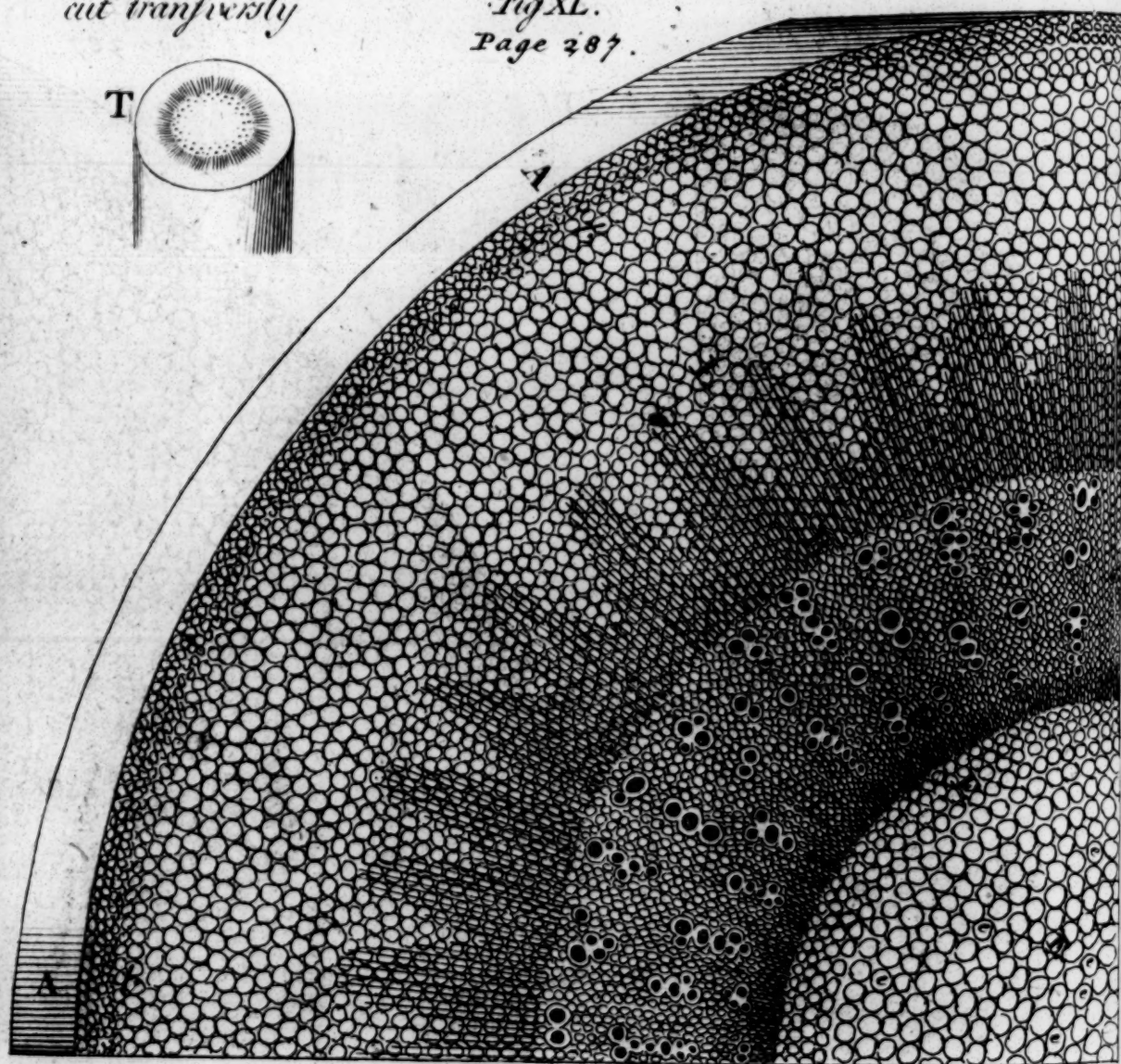


Fig XL.  
Page 287.



and then point out their Uses. To this End, I shall choose two Roots, viz. a Root of *Wormwood*, as Fig. XXXIX. on Plate XXIII, fronting p. 287; and a *Horse-Radish* Root, Fig. XL. on the same Plate; in each of which, T represents the Root cut transversely as it appears to the naked Eye: The other great quadrantal Figures are each a Quarter of the aforesaid Section T, magnified to the Sight by a *Microscope*; which thus enlarged, shews the various organical Parts of which it is composed, and by which Vegetation is performed.

A. And does this Glass, indeed, thus magnify and enlarge the small Section T? What wonderful Discoveries have been reserved for this curious and inquisitive Age! Pray describe to me the different Appearances of those magnified Sections.

B. I will, in the following Order. 1. *Ab* is the Skin or Rind, or outward Membrane including the Root. 2. From A to C in the *Wormwood* Root is the Bark, which is a membranous Substance, consisting partly of a great Number of little Bladders or Vesicles BBB; the same is represented by AB in the *Horse-Radish* Root: It also consisteth in Part of a ligneous or woody Substance, as from B to L in the Root last named. 3. The Wood of the Root is all that Part between B and E in the *Horse-Radish* Root; and from CC, to the very Center in the *Wormwood* Root. 4. The Wood of the Root consisteth also of two different Substances, viz. a ligneous one, properly the Wood, as EEE, and a parenchymous one, like that of the Bark, as DDD,



DDD, inserted regularly between the Portions of Wood ; these are very distinct in the *Wormwood* Root, but in the *Radish* Root, and in several others, they are not so visible. 5. In the Wood you see the Orifices of several Tubes, or hollow Veins *aaaa*, which are the Mouths of Air-Vessels. 6. From G to E, in the *Radish* Root, is another little Circle of Vessels, like those of the Bark. 7. *Lastly*, From E to the Center, in the *Radish* Root, is the Pith, which consisteth of the same parenchymous, or spongy Substance of Bladders, as doth the Bark, and Part of the Wood ; but the Pith is not common to all Roots, as you see there is none in the *Wormwood* Root\*.

*A.* And, pray, what is the Use of the several Parts of the Root now described ?

*B.* The Bladders in the Bark render it a spongy Substance, which therefore is fit to imbibe and suck up the watery Parts of the Soil, which are impregnate with the Principles of vegetable Life and Growth : This impregnated Water imbibed by the Bark is what we call the *Sap* ; the Skin of the Root serving as a Filtre, to strain and purify it at its first Entrance. 2. The *Sap*, thus strained and imbibed, doth ferment in the Substance of the Bark, whereby it becomes farther prepared, and so doth more easily insinuate itself into the parenchymous Sub-

\* The Word *parenchyma* was formerly used to denote that red fleshy Substance which lies between the Interstices of the Vessels in the Bowels, and gives them their Bulk ; as in the *Liver*, *Kidneys*, *Spleen*, &c. from whence it was afterwards used to signify the soft, spongy, or pulpy Parts of any Body, as of the Leaves, Rcots, &c. of Plants. And hence it is usual to say, such Parts are *parenchymous*, that have such a Matter and Texture.



stance of the Root; whereupon, partly by the Appulse of fresh *Sap*, and partly by the pulsive Motion of the extended Bladders of the *Parenchyma*, the *Sap* is forced thence into the other Parts of the Root; and is still more and more strained in its Passage from Bladder to Bladder.

3. The *Sap*, thus distributed through the whole Root, doth supply its organical Parts with those Principles of Nourishment which every one requires; and thus the Root, by the constant Application of those nutritious Principles, receives its *Increment*, *Solidity*, and *Growth*, or *vegetative Life* and *Motion* in every Part.

*A.* To what End do those you call Air-Vessels serve?

*B.* In them is contained a proper Kind of vegetable Air or Vapour, which serveth to ferment the *Sap* now entering the ligneous Part, the better to qualify it for Assimilation, or uniting therewith.

*A.* Why, I pray, do the Roots of some Plants yield a milky Juice or Liquor, and others a clear watery one, when cut?

*B.* Because that in each Root, the Fluid or Liquor of each organical Part is made chiefly by different Filtration of the *Sap* through the Sides thereof; therefore those which strain more freely the aqueous or watery Part of the *Sap*, contain a *Lympha*, or clear Water; and are hence called *Lymphæducts*; and where these are most numerous in Roots, such Roots, when cut, will bleed a *Lympha*. As, on the other Hand, those Vessels, which are disposed to admit the oily or balsamic Part of the *Sap* most copiously, are

T

called

called *lactiferous Vessels*; and Roots, which contain a great Plenty of those, will, when cut, bleed a milky, oily, or balsamic Liquor.

*A.* When the Root is thus formed, and instructed with all its several Organs of Vegetation, as you have now related; pray which is the next Step which Nature takes in the Production of the Plant?

*B.* The Root being now become the Procurator for the future Plant, doth, by extracting from the Earth, by its Vessels, proper vegetable Juices and Aliment, administer or communicate the same to the *Pluma*, or *Seed-Plant* (sustained, till now, from the Substance of the Seed, by the Seed-Root, or Seed-Leaves) and thereby causeth it to shoot forth vigorously and increase, and gradually to swell out or unfold all its Blades, Branches, Buds, Leaves, Flowers, and Seeds again, from various Parts of its Stalk or Trunk.

*A.* Then, I suppose, the same Mechanism, or *Apparatus* of organized Parts, is continued from the Root to the Trunk or Stem of the Plant for the Communication of this vegetable Sustenance; is it not?

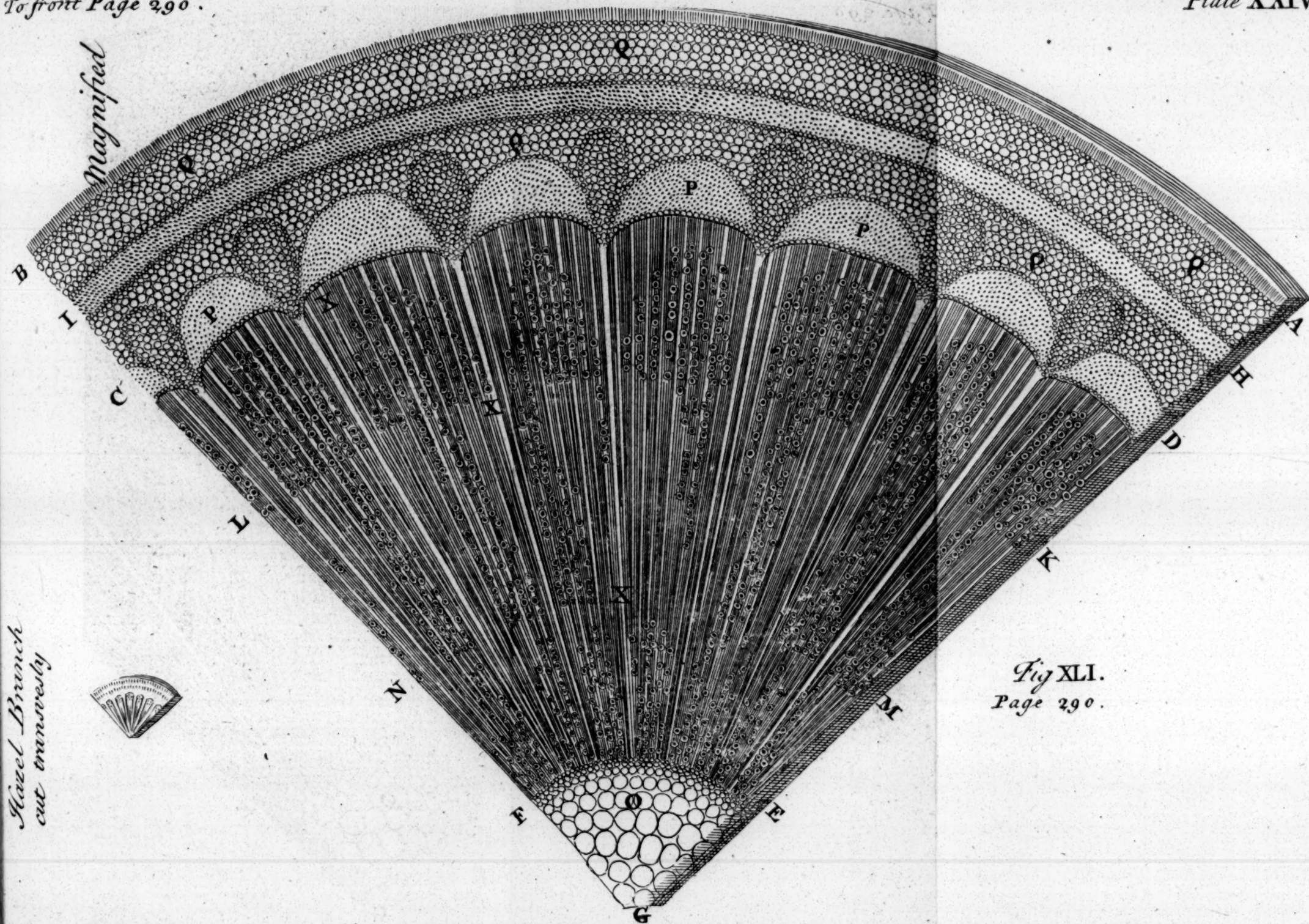
*B.* Yes; and that you may see it is so, I have taken *Fig. XLI.* on *Plate XXIV.* fronting *p. 290.* from *Dr. Grew*, for your Satisfaction: In which *T* represents one Quarter of a Section of a Hasle-Branch, as it appears to the Eye; *AGB* is the same as it appears through a good *Microscope*; wherein *AB* is the Skin; *ABCD* the Bark; *QQQ* the Parenchyma of Bladders, or Sap-Vessels; *HI* a Ring of a special Sort of Vessels; *PP* common Sap-Vessels; *CDEF* the

*ligneous*



To front Page 290 .

Plate XXIV





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*ligneous* Substance, or Wood, of three Years Growth; KLFE the Wood of two Years; MNEF the Wood of the first Year; XX the *parenchymous* Insertions; O the Pith full of Vessels; the black Parcels are the solid Wood; those numerous Holes appearing all over the same, are the Mouths of Air-Vessels: Thus you see the organical Constitution of the Stalk, or Trunk, is the same with that I before shewed in the Root.

A. It is so indeed, and I am surprized to see such wonderous Contrivance and Analogy of the Organization of Vegetables! But, pray, go on.

B. The nutritious *Sap* ascends the first Year of a Plant's Growth by the Vessels of the Pith; after which the Pith becomes dry, and so continues. 2. The next Part, through which the *Sap* riseth, is the Wood, by the Air-Vessels, and that only in the Spring. 3. The third Part, by which it ascends, is the Bark, as before said, the greatest Part of the Year; and this is the general Theory of the Motion of the *Sap* \*.

\* Thus the learned Dr. Grew; but it is a Matter of great Controversy how the Sap ascends, and what Course it takes after it is imbibed by the Roots, whether it is by the *Bark*, the *Pith*, or the *Wood*, or all, as above mentioned. The Retainers to each Hypothesis, and the Arguments produced to support it, see in Shaw's Notes to Boerhaave's Chymistry, p. 146, 147, and 148 of the Theory.

Some Naturalists strongly maintain a *Circulation of the Sap* in Plants and Trees: But the Reverend Mr. Hales, in his *Vegetable Statics*, will not allow it, but endeavours to prove the Contrary, Vol. 1. Exper. 46, &c.

Dr. Boerhaave says, that, since the Sap is furnished by the Earth, it will consist of some *fossile Parts*, some Parts delivered from the *Air* and *Rain*, and others from putrefied Animals. Plants, &c. and that therefore in Vegetables are contained all Kinds of Salt, Oil, Water, Earth, and probably all Kinds of Metals too, since their Ashes always afford somewhat which the Loadstone attracts. *Theory of Chymistry*, by Shaw, Page 147.

*A.* But, since both Root and Branch contain Air-Vessels, pray, in what Part of the Plant doth the Air first enter it ?

*B.* The chief Entrance of Air is at the Root, along with the *Sap* ; but it also enters, more or less, at the Trunk, Leaves, &c. Parts of the Plant : The Air, or airy Part of the *Sap*, being thus raised in its proper Vessels, is filtered through the same into the Vesicles of the parenchymous Insertions in the Wood ; and thus is distributed through all the Parts of the Plant or Tree \*.

*A.* Pray why are the Stalks of some Plants hollow within ?

*B.* Partly for the more expedient Ripening of the Fruit or Seed, which is better effected by a more plentiful Supply of Air by these hollow Trunks ; and partly for the better determining the true Age of the Plant ; for the Air in this Hollow, by drying up the *Sap*, shrinketh the *Sap*-Vessels so far as to hinder the Motion of the *Sap* therein ; whence the Plant must perish of Course : Hence it is, that the greater Part of annual Trunks are hollow.

*A.* Please next to say, whence the Form or Figuration of the Trunks of Plants and Trees proceeds.

*B.* Chiefly from the Air in the Air-Vessels : Thus almost all Shrubs have a greater Number of Air-Vessels, and those of a smaller Size ;

\* Mr. *Hales* has proved, by many curious Experiments, that all Plants perspire in a considerable degree, but *Ever-greens* the least of any. He discovered, that the Quantity of Nourishment, imbibed and perspired in a *Sun-Flower*, is to that of a Man, Bulk for Bulk, as 17 to 1. *Veget. Statics*, Exper. 1.

which,



which, therefore, most easily yielding to the magnetic Attraction of the external Air, do consequently spread much abroad; by which spreading the Air-Vessels do sooner and more easily strike into the Bark, and so produce collateral Buds and Branches, and that upon the first Rising of the Plant from the Root; and thus it becomes a Shrub: But, if the said Air-Vessels are very large, as in Oak, Walnut, Elm, &c. they will not so easily yield or shoot out collaterally; and so the Trunk grows up taller and more entire.

*A.* Why do some Trees run up so very slender, and others so very thick and big?

*B.* This is from the Position of the Air-Vessels; for where they lie most circular round the Center in Form of Rings, as in Elm and Ash, there the Tree in Proportion grows more tall and taper, and less thick: But, when the said Vessels spread more broad, and are postured in Lines from the Center, as in Oak, &c. then the Tree grows very thick; in this Case, the diametrical Growth of the Wood is more promoted than in any other: For which general Reason, also, Trees grow round or angular.

*A.* Pray, how comes it to pass, that several Stalks of Plants have *Joints* or *Knots*? And what is their Use?

*B.* Because, in forming the Branch or Blade, both the Rind and woody Substance thereof are, upon their shooting forth, divaricated from their perpendicular Posture to a cross Position, and as they with the other grow and thrive together,

ther, they bind and throng each other into a Knot. The Uses of Knots are two, *viz.* for strengthening the Stem, and for finer Growth; for the Knots serve to strain and transmit the Juices more refined to the upper Parts, and to the Fruit.

*A.* How do you account for the *Production* and *Textures* of the *Leaves*?

*B.* The Parts of the Leaf are substantially the same with those of the Branch; its Skin is the Continuation of that of the Branch; the Fibres, or Nerves, dispersed through the Leaf, are only Ramifications of the Branch's Wood, or ligneous Body; the parenchymous Substance, which lies between the Fibres, is nothing but the Continuation of the cortical Body, or Substance of the Bark, spread through the same \*.

*A.* Pray

\* The Leaves of Plants (such as have woody Fibres) are easily anatomized, and a Skeleton of the Fibres made as follows:

1. The Leaves must be gathered when full grown, or old, but not dry; then expose them in an open Vessel of Water, and as fast as it evaporates fill it up again.

2. After about a Month or two the Leaves will begin to putrify, or grow soft; and the Pellicle, or thin Skin on each Side, will first begin to separate from the pulpous Part of the Leaves.

3. The Leaf is then to be put into a broad Pan of Water, where you have Room to squeeze the pulpous or green Substance of the Leaf, which must be very gently, and it will easily separate from it, and leave an entire Skeleton of Fibres.

4. Or sometimes I have only laid the Leaf, stript of its Skins or Membranes, on a Piece of Paper, where, after it has lain a little to dry, I have only taken hold of the Tail of the Leaf, and, gently raising it, the Skeleton has freely separated from the Pulp, which adhered to the Paper.

5. In many of these Skeletons, as that of the Apple-Tree, Cherry-Tree, Holm, &c. you will find, that all the Fibres, great and small, are double; or that there are two Layers or Planes of Fibres, which, you will observe, may be easily separated from each other through the whole Skeleton.

6. These

A. Pray what is the Use of *Leaves*?

B. *First*, For Protection, which they afford to each other, and to the Flower in the Bud; as also to the Fruit itself in some Plants. *Secondly*, For Augmentation; for the Capacity for the due Spreading and Ampliation of a Tree, or Plant, are its Leaves. *Thirdly*, They serve to the greater Purity and Preparation of the *Sap*; the grosser Parts of which are retained in the Leaves, while the more elaborate and essential are supplied to the Flower, Fruit, and Seed, as their proper Aliment. *Fourthly*, They serve to Perspiration; for those Orifices, observed to be in Leaves, perform the same Functions in Trees, as the Pores of the Body do in Men; that is, to cause an invisible Perspiration in Plants \*.

A. Pray

6. These two Planes of woody Fibres, which compose the Skeleton of a Leaf, are supposed to be analogous to the Arteries and Veins of an Animal Body. But there is no discerning which are the arterial, and which the venal Fibres. See the Figure of the Skeleton, and its Duplicature, of an Apple-Leaf in Fig. LXVII. on Plate XX, fronting Page 233.

7. After a like Manner may Fruits be prepared, and Skeletons of them procured, as *Apples, Pears, Peaches, &c.* They must be sound and good, pared very nicely, then boiled gently till they are thoroughly soft; then, taking them out, and putting them into a Basin of cold Water, hold the Tail in one Hand, and, with one Finger and Thumb of the other, rub the Pulp gently off, and preserve the Skeleton in Spirit of Wine rectified.

8. Carrots, and other Roots that have woody Fibres, must be boiled without paring till they grow soft, and the Pulp comes off. Not only many Sorts of Roots, but the Bark of several Trees also, may be reduced after this Method into Skeletons, presenting rare and curious Views of Vegetables. *Philos. Trans.* N<sup>o</sup> 414, and 416.

\* Notwithstanding the great Perspiration in Animals and Plants, I never yet could discover any Thing like Pores in the Scarf-Skin of the one, or the fine Membranes which cover the Leaves of the other; though I have often sought them in the most proper Subjects, and with the best Sort of double reflecting Microscopes.



*A.* Pray what do you observe concerning the *Flowers* of Plants?

*B.* In the *Flower* may be observed: 1. The *Empalement*, or *Calyx*, or the Cup, which containeth the Flower, and is designed for the Guard and Security of the other Parts of the Flower. 2. The *Foliation*, or Composure of Leaves, which are of divers Forms and Colours; whose constituent Parts are the same as those of the Leaves, viz. Skin, Parenchyma, Air, and Sap-Vessels. 3. Within the *Foliage* stands the *Attire*; that is, those fine upright Stems with their *Apices*, and the *Style* in the very Middle of all; and these are the general Parts of which the Flower doth consist.

*A.* Pray can you tell the Uses of those several Parts of the Flower?

*B.* The *Empalement*, as I said, is for the Security of the Flower in *Embryo*, and afterwards for the Support of the *Foliage*, to keep the Leaves of the Flower in due and decorous Posture, which

I know Mr. *Leewenboek* (in *Transf.* N<sup>o</sup> 369) tells us, that he has viewed these Pores or Spiracles very clearly in the *Leaves of Box*; and that, on one Superficies of such a Leaf, he has computed 172090 Pores, and on the other as many. The *Royal Society* has received and admitted this to pass for Truth; whereas, I believe it may be easily made to appear, that nothing is more false, and that, instead of seeing 344180 Pores, he never saw one. It is no hard Matter also to point out the Grounds of the Fallacy, or to prove, that this is not the only Error which this *Prince* of the *Virtuosi* has fallen into, and published to the World. But these Matters must be referred to a future Tract on these Subjects. I shall only here observe, that there is something exceeding fine and delicate in the Texture of the Pellicle or fine Membrane which covers the Box Leaf, and also in the Skeleton made thereof. Also that the *transparent Spherules*, or round clear Drops, standing all over the Surface of the Leaves of *Hyssop*, *Mint*, &c. and others of other Forms and Colours on other Plants, make a very pleasant and delightful View in the Microscope.

would

would otherwise hang uncouth and taudry, as a Lady without her Bodice. The *Foliage*, or Leaves of the Flower, defend the Attire, and in some Plants the Fruit; it also serves for the further Refining and Separation of proper Parts of the *Sap* for the Perfecting the Seed. The *Attire* is an Ornament and Distinction in Flowers. It supplies also divers Kinds of small Animals with Food, which harbour therein; that is, in the Hollowness of the Style. *Lastly*, it is supposed, it also serveth as *Male Sperm* to impregnate and fructify the Seed\*.

A. What is the Nature and Composition of Fruit, I pray you?

B. The general Nature and Composition of all Fruit, is one and the same; that is, their es-

\* That there is such a Thing as a *Sex* in Plants; that some Plants are *Male*, others *Female*, and most *Hermaphrodite*; and that the Flower is the *Pudendum* of the Plant, as containing the Parts of Generation; are Points agreed on as certain by modern Naturalists.

2. The *Male Parts* of a Flower are the *Stamina*, or Stems, and their *Apices*, or little Tops, which contain the fine Powder, or *Farina*, which is imagined to be the *Semen*, or Sperm of the Plant.

3. The *Female Parts* are the *Style*, which serves to receive the Semen; and the *Seed-Case* at the Bottom of the Style, which is judged to be the *Matrix*, or Womb of the Plant.

4. Some Plants have only the Male Parts of the Flower, and they never bear Fruit; others the Female Parts only, and they bear Fruit. In others, as *Cucumbers*, *Melons*, *Gourds*, *Walnut*, *Oak*, *Beech*, &c. the *Male* and *Female* Flowers grow at some Distance from each other. But,

5. Most Plants are *Hermaphrodite*, or have the *Male* and *Female Parts* in the same Flower, as the *Pulp*, *Lily*, *Polyanthus*, &c.

6. The Learned can't, as yet, fully prove the Manner of Impregnation and Generation of Plants; it is generally agreed, that the *Farina* falling from the *Apices*, is received by the *Style* or *Pistæ*, which conveys it to the *Seed-Case* below, where it impregnates the Embryo-Seed contained therein. There is much to be said for and against this Hypothesis, a short View of which Controversy the Reader may meet with in *Shaw's Notes to Boerhaave's Chymistry*, Page 149 and 150 of the Theory, and in the other Botanical Authors.

essential

sential and truly vital Parts are in all the same; and but the Continuation of those which I have already observed to you, do constitute the other Parts of the Plant. But, by the different Constitution and Textures of these Parts, divers considerably different Fruits result, as *Apples, Pears, Plums, Nuts, Berries, &c.*

*A.* Pray what are the particular Parts which compose those different Fruits?

*B.* The *Apple* doth consist of these four, *viz.* the *Pilling*, the *Parenchyma* or *Pulp*, *Branchery*, and *Coar.* The *Pear* hath five distinct Parts; the *Pilling*, the *Parenchyma*, the *Branchery*, *Calculary*, and *Acetary.* The *Plum* (to which the *Cherry, Apricot, Peach, &c.* may be referred) consists of four Parts; the *Pilling*, *Parenchyma*, *Branchery*, and *Stone.* The *Berry* consisteth of four Parts; the *Pilling*, the *Parenchyma*, *Branchery*, and *Seed.* The *Nut* consisteth of three Parts; the *Cap*, the *Shell*, and *Pitb.* All which are regularly treated of by Dr. Grew in his *Anatomy of Plants.*

*A.* Pray (to be short) what are the principal *Uses of Fruit?*

*B.* The Use of Fruit is two-fold: For, *first*, it serveth Man (and I may say Beast) as a delicious and pleasant Meat, or Food; besides the various Purposes of Medicine. *Secondly*, It supplies the Seed with a due, and most convenient *Sap*; the Fruit doing the same Office to the Seed, as the Leaves do to the Fruit, *viz.* that, by a due Purification and Exaltation of the *Sap*, the Seed may obtain its Perfection.

*A.* Pray what is the *Seed*, in its State of *Generation?*

*B.* As



B. As the original, so the ultimate End and Perfection of Vegetation, is the Seed. How it hath been in its State adapted to Vegetation, we have already seen. Its State of Generation is as follows: The *Sap*, having in the Root, Trunk, and Leaves, passed divers Concoctions and Separations, is now, at last, in some good Maturity, advanced towards the Seed. In the Fruit, as was said, it is still farther prepared, and the more essential Part is transmitted into that particular Part of the Branchery, called the *Seed-Branch*; which, because it is a good Length, and very fine, doth yet farther mature the *Sap* in passing through it: In this mature State, it is conducted through the Seed-Branch into the Coats of the Seed, as into the Womb. The meaner Part of the *Sap* to the outer Coat, the more fine is transmitted to the inner Coat, where it is farther prepared by Fermentation; and thence is filtered through a fine Skin into the inmost Part or Substance of the Seed, and there becomes a Liquor fit for the actuating the future Embryo-Seed, or causing it to vegetate, and the Plume to shoot forth.

A. But pray, *Sir*, before you quite dismiss the Subject of Plants, please to let me know what you think of *Moss*, *Mushrooms*, and those *fungous Excrescences* adhering to the Sides of Trees?

B. *Mushrooms*, *Moss*, and other *fungous* Substances, are a spurious Kind of Plants, or which may be called excrementitious Plants, since they arise intirely from the Bodies of other Plants, or from a Kind of viscus Mucilage of the Earth: They grow, indeed, and have Roots, some inserted  
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into the Fibres of the Plant producing them, as *Mistletoe* is radicated into the Fibres of the Oak; and *Moss* to the Fibres of the Barks of Trees. *Mushrooms* arise from various Matters in Earth or Wood, and are found to consist of a vast Bundle of Fibres, proceeding from the Substance on which they grow; these make the Stalk, and thence divaricating, spread and extend themselves into a spherical Canopy, or Head, which contains a succulent Parenchyma; on the under Part of which, I am apt to think, the Seed may be produced, (though none hath hitherto been seen) which being wafted about by the Wind, falls in divers Places of the Earth, and there takes Root and grows: Thus *Moss* undoubtedly bears Seed, by which the various Sorts thereof are propagated; though, for their Smallness, they cannot be seen\*.

A. I am

\*1. Of *Moss*, Naturalists make mention of about 300 different Kinds; though those which grow common are not above 50. They have great Variety in their Growth, Form, and Make; and most of them afford an agreeable Sight in the Microscope. I never could discover any Thing like Flower-Seeds in many of them; and therefore they are truly judged to be Plants of their own Kind.

2. Dr. *Lifter* takes the Gills of Mushrooms to be the very Flower and Seed of the Plant; indeed no other can be discovered by the Microscope. The *Mouldiness* on Leather, Paste, Pickles, &c. is of the *Mushroom* Tribe; they are well known to be of a speedy Growth; they consist of Multitudes of fine Stalks or Stems; on the Tops whereof grow round Heads, containing a Kind of Liquor, as I have often found by bruising them under the Microscope.

3. The *Fungi*, or what we call *Jews-Ear*, *Agaric*, &c. which grow on the Rind of Trees, are of a very porous Substance; if the Superficies of some be viewed with a Microscope, it will appear like a Honey-Comb, full of Holes, which go deep, and make a fistular Substance. In these there is still less discernible of Roots, Flowers, or Seed.

4. The

A. I am greatly obliged to you, Sir, for this concise and regular Epitome of the *Science of Vegetation*; and consequently the *true Theory of Plants*: I never understood so much before, nor, indeed, have I Time to peruse *voluminous Authors*.

4. The *Puff-Balls* are another odd Sort of Production; these at first have a fleshy Substance pretty firm, which by Degrees becoming more ripe, changes to a Kind of Dust, which Mr. *Bradley* takes to be the *Seed*.

5. The *Truffle*, like the *Puff-Ball*, is formed under Ground; it lies about six or eight Inches deep; is of a firm and fleshy Substance within, and cortical without; the fleshy Part, if viewed in thin Slices under the Microscope, appears to be composed of roundish, opaque, and very small Particles, thickly interspersed through a white, transparent, and seemingly vascular Substance, which runs in large and finer Veins all over the Substance of the *Truffle*. They are of two Kinds, one round, the other of an Egg-like Figure. They are of a strong and very disagreeable Odour; but are esteemed in Food as a very delicious and luxurious Piece of Dainty. They are found very common in the Woods of *Italy* and *France*; and, of late, in divers Parts of *England*. And Dogs are here taught to hunt them out with as great Sagacity, and as easily, as to set Game.

6. As to what relates to the *Submarine Vegetables*, or those which grow in and under the Sea, as the large green membranous *Seabelts*, which grow on Stones; the *Tuci*, and other *Sea-Weeds*; the *Coralines* on Stones and Oyster-shells; the *Sea-Fan*; the *Coral*, which grows on *Rocks*; the *Sponge*, &c. they are so numerous, and various, as not to be treated of here; only this I shall observe, in general, that they appear to be deficient in Roots, Flowers, and Seeds; and are most of a very wonderful Texture and Make, especially the *Sponge*, which makes the finest of Spectacles in the Microscope.

7. For Abundance more on this Head, consult Dr. *Grew's* and *Malpighi's Anatomy of Plants*. *Tournefort's Instit. rei Herbariæ*. *Bradley on Gardening*, and his *Philosophical Account of the Works of Nature*. The *Speſtacle de la Nature*, Vol. II. *Miller's Gardener's Dictionary*, Fol. *Ray's Method and History of Plants*. *Hales's Vegetable Statics*, Vol. I. *Pomet on Drugs*. *Clerici Phys. Lib. IV. Cap. 1, 2, 3*. *Shaw's Notes to Boerhaave's Chymistry*, Page 142, &c. *Derham's Physico-Theology*, Book X. The *Philolog. Library*, under the Title *Botany*, Page 431. *Chambers and Harris's Lexicon. Philosoph. Transf. abridged by Lowthorp*, Vol. II. Chap. 5. *Jones's Continuation*, Vol. IV. Part 2. Chap. 5. *Eames and Martyn's Continuation*, Vol. VI. Part II. Chap. 5.



## C H A P. V.

ZOOGRAPHY, or the PHILOSOPHY of ANIMALS; of the HUMAN BODY, and its solid and fluid Parts; a SURVEY of the Nature of BEASTS, of FOWL, of FISHES, of INSECTS, of REPTILES, of SHELL-ANIMALS, &c. of Health, Disease, Vigilance, Sleep, Dreams, Hunger, Thirst, Death.

A. P R A Y what is the Etymology of the Word Zoography?

B. It is composed of the Greek ζῷον, an Animal, or Living Creature, and γραφή, a Description; and thence it imports a physiological Description of the Nature and Properties of a Living Creature, which we call by the general Term *Animal*.\*

A. How

\* 1. The Word *Animal* is a Derivation from the Latin Word *Anima*, which Word, with the Romans and all Latin Writers, signifies the *Soul*: Now let us see what Ideas the *Latins* expressed by this Word, that we may have the better Notion of what we call the *Soul*, and how far Animals have a Share therein.

2. The Word *Anima* was derived from the Greek ἀνεμῶ, which signifies the *Wind* or *Air*, which therefore must be the original, or primary Sense of this Word; and so *Virgil* uses it, *Quantum Ignis Animæque valent*, *Æn.* 8. Secondly, it was used for the *Breath*; thus *Plautus*, *An fœtet Anima Uxoris suæ?* Thirdly, it was often used for the *Body*. Fourthly, for the *Mind*; which was generally expressed by another Word, *Animus*. Fifthly, it sometimes signified the *Passions*; as, *Comprime Animam*, *Plaut.* Sixthly, the most usual Signification of all, was the *Life*, or that Principle by which Bodies *live, move, and have Sense*.

3. In Greek, what we call *Animal*, is called simply ζῷον, a *Living Creature*, from ζῆν, to *live*. The *Greeks* indeed have a Word for the *Soul*, viz. ψυχή; but then this Word also was derived from the Word φυσῶ, to *blow, to breathe, to cool, &c.* and so hath no other Signification in the original Use, than that of the *Breath, or Blast of Wind*; after which, it comes to be used for the

A. How many Sorts of *Animals* are there ?

B. *Naturalists* generally distribute *Animals* into seven great Kinds, viz. (1.) *Rational Animals*, or Mankind. (2.) *Quadrupeds*, or four-footed Beasts. (3.) *Birds*, or Fowl. (4.) *Fishes*. (5.) *Insects*. (6.) *Reptiles*. (7.) *Conchilious*, or *Shell-Animals*. Of each of these we will take a short Survey; and then conclude with a few Reflections on the common Accidents of Animal Life.

A. I presume your intended Survey of *Man* will extend no farther than the *Animal Part*; pray, therefore, what are the *Component Parts* of our Bodies ?

B. The human Body consists of *solid* and *fluid Parts*, which in general are called the *Solids* and *Fluids*, or *Humours* of the Body.

A. What are the general Divisions of this Part of *Philosophy* ?

B. I shall here divide it with respect to the different Perfection of *Animals*; viz.

1. *Anthropography*, of the human Body.

the *Body*, the *Life*, and the *Mind*, all which Senses are frequent in the New Testament, and other *Greek Writers*.

4. Lastly, the Words which signified the *Soul* among the *Hebrews*, were two, viz. נפש, which signifies the *sensitive Soul*: And נשמה, the *human* or *rational Soul*; but both these Words, likewise, in their original and primary Sense, were used for *Halitus*, *Flatus*, *Respiratio*, that is, for the *Breath* or *Respiration* in *Animals*. See *Gen.* ii. 7. *Job* xxxvii. 10. *Isaiah* ii. 22, &c.

5. Now if the Words in three original Languages, which were used for the *Soul*, do primarily mean no more than the *Breath*, and, at most, the *Life* of Living Creatures, I think, it is evident that all Creatures which *breathe*, and have *Sense* and *Life*, may properly, yea *literally*, be said to have a *Soul*; which *Soul*, in all *Animals*, is in a greater or lesser Degree perfect, according as their *Faculties* and *Powers* of *Life*, *Sense*, and *Mind*, are so.

2. *Zoo-*

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2. *Zoography*, of the Bodies of *Brutes* in particular.

3. *Ornithography*, of the Nature of *Birds* or *Fowl*.

4. *Ichthyography*, of the Nature of *Fishes*.

5. *Entomatography*, of the Nature of *Insects*.

6. *Herpetography*, of the Nature of *Reptiles*.

7. *Zoophytography*, of the Nature of *Shell-Animals*.

*A.* Pray what do you particularly include under the first Division, which you call *Anthropography*?

*B.* A brief physiological Description of all the component Parts of the *human Body*; which Parts are of two different Kinds, *viz.* *Solids* and *Fluids*.

*A.* Which are the *solid Parts* of the human Body?

*B.* Those which follow: 1. *Bones*. 2. *Cartilages*. 3. *Ligaments*. 4. *Muscles*. 5. *Tendons*. 6. *Membranes*. 7. *Nerves*. 8. *Arteries*. 9. *Veins*. 10. *Ducts*, or fine tubular Vessels of various Sorts. Of these simple Solids the more *compounded Organs* of Life consist.

*A.* Pray, which are those *compound Organs* of Life?

*B.* The *Brain*, and *Cerebellum*; the *Lungs*; the *Heart*; the *Stomach*; the *Liver*; the *Spleen*; the *Pancreas*; the *Kidneys*; the *Glands*; the *Intestines*; together with the *Organs* of Sense, *viz.* the *Eyes*; the *Ears*; the *Nose*; the *Tounge*.

*A.* Which



A. Which are the *fluid Parts* of the human Body?

B. They are these: 1. The *Chyle*. 2. *Blood*. 3. *Saliva*, or Spittle. 4. *Bile*. 5. *Milk*. 6. *Lympha*. 7. The *Semen*. 8. The *pancreatic Juice*. 9. *Urine*. 10. *Phlegm*. 11. *Serum*. And, 12. The *aqueous Humour* of the Eyes.

A. Pray what is a *Bone*, and how generated?

B. A *Bone* is a Bundle of hard Fibres, tied to one another by small transverse Fibres. In the *Fœtus* those Fibres are porous, soft, and easily discerned; it is probable they are nourished by the serous Part of the Blood. As their Pores fill up with a Substance of their own Nature, so they increase, harden, and grow close; thus when the Pores are full of this Substance, the Bones are grown to their utmost Extent, Hardness, and Solidity.

A. Are there not *divers Sorts* of Bones in the Body?

B. Yes; some are hollow, and filled with *Marrow*; others are *solid* clear through; some are very *small*, others very *large*; some are *round*, and others *flat*; some are *plane*, others *convex*, or *concave*; where they are joined to each other, they make the various *Joints* throughout our Bodies.

A. Pray what is the *Use* of the Bones?

B. They are in us, as the Timber in the Building; the Use of which is to give *Strength*, *Firmness*, *Solidity*, *Form* and *Beauty* to the Whole.

A. Pray can you tell the Number of Bones in a human Body?

B. Dr. Keill has reckoned 245; others make them to be 249, viz. In the Skull 14; in the Face

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and

and Throat 46 ; in the Trunk 67 ; in the Arms and Hands 62 ; in the Legs and Feet 60.

*A.* What do Bones yield by a *chymical Analysis* ?

*B.* They produce much *volatile Salt* and *Spirit*, which are very subtle and penetrating; some *Sulphur*, very stinking ; a little *Phlegm*, and much *Earth*.

*A.* What is that Part you call a Cartilage, I pray you ?

*B.* A *Cartilage*, or Gristle, is a smooth and solid Body, softer than a Bone ; in it are no Cavities or Cells containing Marrow, nor is it covered with any Membrane to make it sensible, as are the Bones. The *Cartilages* have a natural Resort or Elasticity, whereby they retrieve their natural Figure or Situation. They are chiefly in those Places where a soft and easy Motion is required, as in the *Ears*, *Nose*, *Wind-pipe*, &c. They cover also the Ends of all the Bones that are joined together for Motion.

*A.* Pray what are their *Uses* ?

*B.* They are appointed for the special Structure of some Parts, as the *Ears*, *Nose*, &c. and for the easy Motion of the Bones in the Joints.

*A.* What do you call a Ligament ?

*B.* A *Ligament* hath its Name from *Ligo*, to bind, and is a white solid Body, softer than a Cartilage, yet harder than a Membrane ; they have no Cavities containing Marrow, nor any Sense : Their chief Use is to bind and fasten the Bones (in their Articulation) together, lest they should be displaced by any violent Motion.

*A.* Pray what is a *Muscle* ?

*B. A*



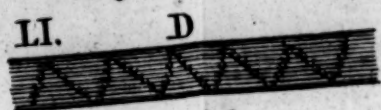


Fig I. A To front Page 307.



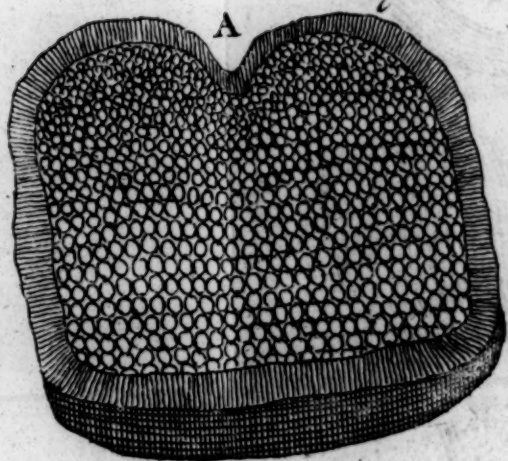
Page 329.

Fig II. D



Page 329.

Fig III. Page 337.



a  
D

b

LIII B



C

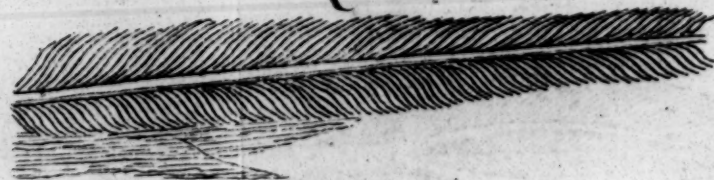


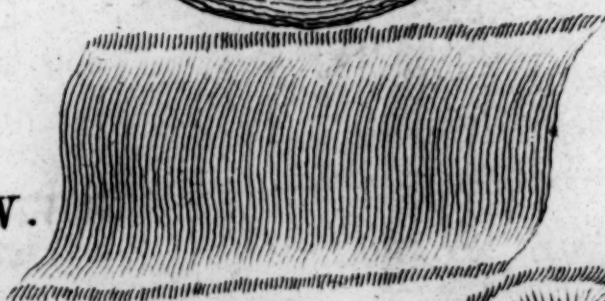
Fig XII.



XLIII.



XLIV.



XLV.

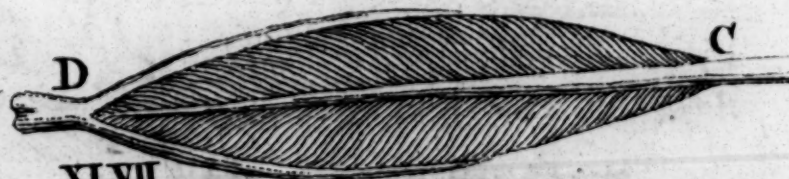


XLVI.



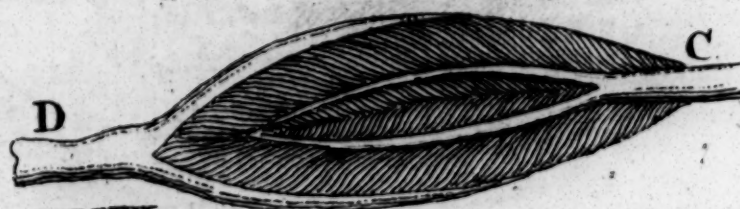
D

XLVII.



D

XLVIII.



XLIX



B. A *Muscle* is a Bundle of fleshy, and often tendinous Fibres; of which all in the same Plane are parallel to one another, and are all inclosed by one proper Membrane. The fleshy Fibres compose the Body (called the Belly) of the Muscle; and the tendinous Fibres, the Extremities: Thus, in *Fig. XLII.* on *Plate XXV.* fronting *p. 307.* AB is the Belly of the Muscle; C is its Head, and D its Tail, both tendinous.

A. How many *Sorts* of Muscles are there?

B. Several: Some being long and round, as *Fig. XLII.*; some plane and circular, as *Fig. XLIII.*; some broad, whose Fibres lie spiral-wise, as *Fig. XLIV.*; some broad, whose Fibres run straight, as *Fig. XLIV.*; some whose Fibres lie divaricated, or converge from their Beginning to a narrow Tendon, as *Fig. XLVI.*; some are double, which consist of a Tendon running through its Body from Head to Tail, and a Row of Fibres on each Side, as *Fig. XLVII.*; some are yet more double, having two or more tendinous Branches running through them, with various Rows and Orders of Fibres, as *Fig. XLVIII.*; some have only a small long Body, which divides into several small Tendons at the End, as *Fig. XLIX.*; others also have two Bodies proceeding from one Head; and there are others yet of a different Sort from any here described. Note, all the *Figures* above referred to are on *Plate XXV.* fronting this *p. 307.*

A. What is the *Use* of *Muscles*?

B. 1. They constitute the fleshy Part of our Bodies, and give it that beautiful Form we observe over all its Surface. 2. But they principally serve for animal Motion; for by their Means



all the Parts of the animal Body are moved.

*A.* How is that Motion performed?

*B.* Thus; each Muscle, and every Fibre in a Muscle, hath *Nerves, Arteries and Veins*, attending it; now by the Rarefaction of the Blood and Spirits in those Vessels, their Cavities are distended; the Muscle must then swell of Course, and swelling, will contract and become shorter: Therefore the *Bone*, or Part, into which the Muscle is inserted, will, by this Contraction of it, be drawn or pulled towards that Part where the Muscle arises; and this is the general Theory of all *animal Motion*.

*A.* Pray what *Number of Muscles* may there be in a human Body?

*B.* Dr. Keill numerates 446 single Muscles in the whole Body; but others (less knowing) have reckoned different Numbers.

*A.* Pray what do you understand by a *Tendon*?

*B.* A *Tendon* is a Part consisting of nervous Fibres, void of any *parenchymous* or fleshy Substance, invested in a Membrane common to all the Muscles; and form what we call the *Head C*, and *Tail D*, of all Muscles; or those Parts by which they arise from, or are inserted into the Bones of the several Limbs of the Body: The Number of Fibres in every Tendon is equal to that of the Fibres of the Muscle, and are the same Fibres with them; they are those white, hard, compacted Bodies, which we vulgarly call *Sinews*.

*A.* What Part is that you call a *Membrane*?

*B.* A *Membrane* is a Web of several Sorts of Fibres, interwoven for the covering and wrapping up of some Parts; hence they are elastic, and of an



an exquisite Sense ; here the innumerable Divisions, Windings, serpentine Progressions, and frequent Inosculations of Veins with Veins, and Arteries with Arteries, make a most agreeable Embroidery, and delicate Net-work, covering the whole Membrane.

*A.* Pray, *Sir*, what is the *Use* of *Membranes*?

*B.* To cover and wrap up the Parts ; to strengthen them ; to save them from external Injuries ; to preserve the natural Heat ; to join one Part to another ; to cause an exquisite Sense ; to separate an Humour (by its Glands) for moistening the Parts, &c.

*A.* Are there not divers Kinds of *Membranes*?

*B.* Yes ; as the *Scarf-Skin*, covering the whole Body ; the *Skin* of the Body itself ; the *Meninges* of the Brain ; the *Pleura* in the Breast ; the *Pericardium* involving the Heart ; the *Periostium* investing the Bones : The *Tunics* or Coats of the Vessels, as the Stomach, Bladder, Veins, Arteries, Intestines, Testicles, &c. are all *Membranes* of different Kinds.

*A.* Pray what do you call a *Nerve*?

*B.* A *Nerve* is a long and small Bundle of very fine Pipes, or hollow Fibres, wrapped up in the *Membranes* of the Brain, from whence they have their Beginning.

*A.* What do you find to be the *Use* of the *Nerves*?

*B.* It is very probably supposed, they are the immediate Organs of all Sensation ; for to every external Organ of Sense, as the Eye, the Ear, the Nose, the Tongue, are detached one or more Pair of those Nerves from the Brain ; also those Nerves which proceed from the spinal Mar-

row, are spread through all Parts of the Muscles and their Membranes, and to every Point in the Superficies of the Body ; and thereby make the whole sensible.

*A.* Pray by what Means do the Nerves render the Parts sensible ?

*B.* It is imagined, they do it by the Motion of an exceeding fine and invisible Fluid they contain, called the *animal Spirits* ; by which Impressions are communicated to the Mind (whose Seat is in the Brain) from all Parts of the *animal Body*.

*A.* How many, or what Quantity of Nerves, may there be in the Body ?

*B.* There be *ten Pair*, which proceed from the medullary Substance of the Brain, which are chiefly distributed to all the Parts of the Head and Neck ; from the spinal Marrow there proceeds, through the Vertebrae, *thirty Pair* to all the other Parts of the Body ; and thus, in all, there are *forty Pair* ; for they come forth originally by *Pairs*.

*A.* Pray what do you call *Arteries* ?

*B.* *Arteries* are those Pipes, Tubes, or Channels, which convey the Blood from the Heart to all Parts of the Body.

*A.* What is their *Composition* or *Texture* ?

*B.* They consist, or are composed of three Coats, *viz.* The *first* seems to be a Web of fine Blood-Vessels and Nerves, for nourishing the Coats of the Artery. The *second* is made up of circular, or rather spiral Fibres ; of which there are more or fewer Lays, according to the Bigness of the Artery. The *third* and inmost Coat

is a fine, dense, transparent Membrane, which keeps the Blood within its Channels. The Arteries branch out into various Ramifications, and become invisibly small at last.

A. Pray whence is that *Pulsation* we find in several Parts of our Bodies?

B. This is a Motion of the Arteries only; the Blood being thrown out from the left Ventricle of the Heart into the great Artery, some and some at a Time, presseth the Sides of the Artery, and causes an intermitting Dilatation thereof; which is continued by the constant pulsive Motion of the Blood, and the Spring or Elasticity of the Artery acting on it; hence therefore ensues a constant *alternate Dilatation* and *Contraction* of the Coats of an Artery, and is what we properly call the *Pulse*.

A. Pray what is the *Difference* between *Arteries* and *Veins*?

B. *Veins* are only a Continuation of the capillary Arteries at their Extremities, and convey the reflux Blood back again to the Heart; in their Return they unite their Channels as they approach the Heart, and form at last the three large Trunks, viz. the *Vena Cava Ascendens*, *Descendens*, and the *Vena Porta*, as they are called.

A. How happens it that Veins have no Pulse?

B. Because the Blood is poured into them at the *Anastomosis* in one continued even Stream; and because it moves from a narrower Channel to a wider; the Pressure of the Blood against the Sides of the Veins being less than that against the Sides of the Arteries.



*A.* Pray what do you call those *Ducts*, or *tubular Vessels*, you mentioned under the last Head of solid Parts?

*B.* Those small, fine, hollow Pipes or Tubes dispersed through all Parts of the Body; which convey, some a *Lymph*, called *Lymphæducts*; others a *milky Liquor*, called *lacteal Veins*; and others convey other *Juices* and *Humours* of the Body to their proper Places.

*A.* Having thus heard you on the Nature and Use of the more simple Solids, I shall be obliged to you for a small Account of the more compound solid Parts, which you call the great *Organ of Life*: And, pray, what is the Nature of the *Brain*?

*B.* The whole Substance of the *Brain* is divided into two Parts; that which lies in the Fore-part of the Skull, called the *Cerebrum*; and that lying in the Back-part, called the *Cerebellum*. In the *Cerebrum*, or Fore-part of the Brain, there are observed two Kinds of Substances, the external and internal; the external Substance is soft, glandulous, and of the Colour of Ashes; this Part receives the capillary Branches of the Veins and Arteries belonging to the Brain, and sendeth from its little oval Glands an infinite Number of Fibres, which all together make up the medullary Substance of the internal Part of the Brain and *Cerebellum*, which going out of the Skull, form the *Nerves* and *spinal Marrow*.

*A.* What is the Use of the Brain?

*B.* The Use of the Brain is to separate, from the Blood brought thither, the finest and subtlest Parts thereof, called *animal Spirits*, by the Glands

Glands in the external Part, which are received from those Glands by the Fibres of the medullary Substance, and are from thence conveyed by the Nerves (which these Fibres compose) to all Parts of the Body ; giving the Faculty of *Sensation* to the whole.

*A.* Pray what is the Nature of the *Lungs*?

*B.* The Substance of the *Lungs* is composed of an infinite Number of little Lobes or Spheres, of various Figures and Magnitudes, whose Surfaces are so adapted as to leave but few and small Interstices ; these small Lobes are disposed like so many Branches of Grapes on the Sides of the Branches of the Wind-pipe : Each little Lobe contains, within its own proper Membrane, an infinite Number of small and round Bladders, which leave small Interstices between, full of small Membranes, like those which bind the Lobes together : The Extremities of the Branches of the Wind-pipe open into the Cavities of these small Bladders, which are probably formed by its Membranes ; but the fine Blood-Vessels are only spread upon the Bladders like a Net, with frequent and large Inosculations.

*A.* What is the *Use* of the *Lungs*?

*B.* This is the *great Organ of Breathing* or *Respiration* ; as the Air by its Weight forceth into every Cavity, so as soon as the Fœtus is born, it rushes into the Cavity of the Lungs, and fills the little Vesicles, and by extending them, compresses the small Blood-Globules in the Vessels spread upon them ; this Compression is much greatest when the Air is expelled out of the Lungs by the Contraction of the Breast ; and by this Compression,

pression, the red Globules of Blood, which, through their languid Motion in the Veins, were grown too big to circulate, are again broken and divided into the Serum, and so the Blood is anew made fit for Nutrition and Secretion. Dr. *Keill* also thinks that the Air doth hereby enter and mix with the Blood. Dr. *Cheyne* saith, the elastic Globules of the Blood are hereby formed. And others hold other Opinions of the Use of Respiration. But I think it strange that *Etmuller*, amongst his fourteen Uses thereof, has not mentioned the *vital Spirit* of the Air, which probably is thereby intermixed with the Blood, and diffused through all the Body, and is therein the *Principal of animal Life*; since it is well known Animals cannot live in Air deprived of this Spirit. Neither has Mr. *Derham* hinted any Thing concerning it.

*A.* Pray what is the *Nature and Composition* of the *Heart*?

*B.* The *Heart*, (saith *Boerhaave*) and its *Auricles*, are real Muscles, and act with a muscular Power; for all the Fibres gradually growing shorter, diminish the Length of the Heart, and increase its Breadth; they accurately streighten the Cavities of the Ventricles; dilate the tendinous Mouths of the Arteries; determine the Valves of the Mouths of the Veins for the Stoppage of their Contents; and drive, with great Force, its contained Blood into the dilated Mouths of Arteries, in order to its Circulation through the Body.

*A.* Pray what is the *principal Service* of the Heart to the human Body?

*B.* This



B. This wonderful Muscle has two Motions, which they call *Systole*, and *Diaστοle*; the *Systole* is when the Fibres contract and streighten the Cavities; the *Diaστοle* is when this Muscle ceaseth to act; its Fibres return to their natural Site and Tone, and its Cavities become large and wide. Now the *Vena Cava* returning to the Heart, the exhausted superfluous Blood, with the Chyle newly mixed herewith, pours it through the right Auricle, whence it is detrued into the right Ventricle or Cavity of the Heart; by its *Systole*, it is thence driven into the *pulmonary Artery*, which conveys it to, and distributes it through all the Parts of the Lungs; the Blood being here, by Respiration, prepared, reduced, mixed and impregnated with the *vital Spirit*, and *nutritious Principle* of the Air, is remanded back again by the *pulmonary Vein* to the *left Auricle*; thence into the *left Ventricle* of the Heart, which is then in its *Diaστοle*; lastly, in the *Systole* of this Ventricle, the Blood now refected is thrust into the great Artery, called the *Aorta*, which carries it again through all the Body: Thus the *Heart* is the instrumental Cause of the *Blood's Circulation*.

A. In the next Place, please to give me some Account of the Nature of the *Stomach*.

B. The *Stomach* is composed of four Membranes: The *first* and *inmost* is a large muscular Coat, lying in Plaits, and containing a great Number of Glands, thence called the *Tunica Glandulosa*. The *second* Coat is much finer and thinner; is altogether nervous, and therefore of exquisite Sense. The *third* Tunicle is made of  
straight

straight and circular Fibres; so that by this muscular Coat the Ends of the Stomach are drawn towards its Middle, and the Whole is equally contracted. The *fourth* is the common external Cover of the whole Stomach; it proceeds from the *Peritonæum*.

*A.* To what *Use* doth the Stomach serve?

*B.* The Use of the Stomach is *Digestion*; which is the Dissolution or Separation of the *Aliments* or Food into such minute Parts as are fit to enter our *laëteal Vessels*, and circulate with the Mass of Blood: This is principally effected by the *Saliva*, or Spittle of the Mouth; the fermenting Juice in the Stomach, separated by its aforesaid Glands; by the Liquors we drink; and, *lastly*, by the continual Motion of the muscular Coats of the Stomach, whose absolute Power is, by *Pitcairne*, demonstrated to be equal to  $117088\frac{1}{2}$  Pounds Weight; to which, if the absolute Force of the Diaphragm and Muscles of the Abdomen be added, the Sum will amount to 250734 Pounds Weight; which is above 2238 Hundred Weight, or near 112 Tons: No wonder then the very hardest Diet, or Bones themselves, should so soon be reduced to a liquid Substance, we call the *Chyle*, by such prodigious conspiring Forces!

*A.* What is the Composition of the Liver?

*B.* The common Membrane being raised, the Substance of the *Liver* seems to be composed of small Glands of a conic Figure, and bound together by a proper Membrane into several Heaps or Lobes, which, like Bunches of Grapes, hang to the Branches of the Vessels, (*viz.* the *Vena Porta*,

*Portæ*, and the *Vena Cava*) from which each small Gland receives a Twig, and the Lobes are tied to one another by fine Membranes, which fill up the Spaces between them; and thus the parenchymous Substance of the Liver is formed.

A. What is its Use?

B. The *Vena Portæ* brings the Blood to the Liver full of *Bile*, for its Secretion by the Glands of the Liver; and the *Vena Cava* carries back the Blood, which remains, to the Heart. The *Bile* thus strained from the Blood is, by small Vessels, brought to the *Gall-bladder*, one Part; and the other Part is separated immediately into the Duct, called the *Portus Biliaris*; this Duct going out of the Liver, joins the Neck of the Gall-bladder at some Distance, and forms one common Duct, called the *Choledochus*, through which both Sorts of *Bile* mix and pass to the Lower-end of the *duodenum* Gut, whereinto it flows, in order to mix with the Chyle: Thus the Use of the Liver is to *separate the Bile from the Blood*.

A. Pray what is the Nature and Make of the Spleen?

B. The Substance of the *Spleen* (contained within two Membranes) is composed of an Infinity of Membranes, which form little Cells and Cavities of different Size and Figure, which communicate with one another, and are always full of Blood.

A. What is the Use thereof?

B. The Ancients knew nothing of its Use; nor can the Moderns do more than conjecture at it. You may see Dr. *Keill's* ingenious Hypothesis of



its being Nature's *Storehouse*, in which she deposits the arterial Blood for the Use of the Liver, in his *Anatomy*; and the learned Disquisitions of the great *Boerhaave* on this Subject, in his *Institutions*, Page 139.

*A.* What is that you call the *Pancreas*?

*B.* It is the same as is vulgarly called the *Sweat-bread*; it is called *Pancreas* from *παν*, all, and *κρέας*, *Flesh*; as much as to say, *a Part all Flesh*: It is composed of an infinite Number of little Glands, itself being only a large Gland of the conglomerate Kind; whence its Substance, as we find, is always soft and supple.

*A.* Pray what is its *Use*?

*B.* To screen from the Blood, brought thither, a Liquor called the *pancreatic Juice*, which is conveyed by a proper Duct to the *duodenum Gut*, there to dilute the *Chyle*.

*A.* What is the Substance of the *Kidneys*?

*B.* The *Kidneys* are likewise two large Glands, whose parenchymous Substance is composed of an Infinity of very small Glands, every where interwoven in the Net-like Inosculations of the fine capillary Branches of their Arteries and Veins: From each small Gland proceeds a long small Tube; these Tubes approaching towards the Cavity of the Reins gather together in little Bundles, and from the inner Substance of each Kidney.

*A.* Is not their Use to separate the Urine from the Blood?

*B.* Yes; the Blood being conveyed to them by the *emulgent Arteries*, hath its serous briny Part strained off by their little Glands, and then

is returned again by the *emulgent Veins*; the *Urine*, thus separated, runs down by the *Ureters* into the *Bladder*.

*A.* Pray what is the *Nature* and *Texture* of the *Glands*?

*B.* The Moderns have reduced all the Glands of the Body to two Sorts, *viz. Conglobate Glands*, and *Conglomerate Glands*. A *Conglobate Gland* is a little smooth Body wrapped up in a fine Skin, by which it is separated from all other Parts, only admitting an Artery to pass in, and a Vein and excretory Canal to come out: Of this Nature and Sort, are the Glands of the *Brain*, of the *Lips*, and of the *Testicles*. A *Conglomerate Gland* is composed of many little *Conglobate Glands*, all tied together, and wrapped up in one common Tunicle or Membrane, whose various excretory Ducts uniting, form one or more larger Pipes, or evacuating Vessels: Of this Sort are the *Breasts*, the *Sweet-bread*, the *Kidneys*, &c.

*A.* Their Use I understand is *Secretion of Humours from the Blood*?

*B.* It is so: Thus, the Glands of the Brain seern the *Animal Spirits*; those of the Mouth, the *Saliva* or Spittle; those of the Breasts, *Milk*; those of the *Reins*, *Urine*; those of the *Liver*, *Bile*; those of the *Testicles*, the generative *Semen*; and those of the Skin, the insensible Matter of Perspiration, or Sweat. The Number of these small *cuticular Glands* is somewhat wonderful; it is supposed, that one Grain of Sand will cover no less than 125000 of them; if then we reckon only 2000 of these Grains to an Inch Square,  
and

and allow, at a *Medium*, the Surface of a Man's Body to be equal to 14 square Feet; then there will be of those small Glands in the Skin, the Number of 324000000000; each of which contains a *Pore*, or invisible *Spiracle*, through which we constantly perspire\*.

*A.* Pray what Quantity of Matter goes off by this *insensible Perspiration*?

*B.* *Sanctorius* tells us, in his *Aphorisms*, that by weighing himself he has found, 1. That a Man *sleeping* perspires twice as much as when *awake*. 2. That a sound Man, in one Night of seven Hours Sleep, generally perspires fifty Ounces; or three Pounds *Avoirdupoise*, or four Pounds *Troy Weight*. 3. That scarce half a Pound of this perspires in the first five Hours. And we cannot wonder hereat, since it appears there are above three hundred thousand Millions of Pores in the Body of a middle-sized Man; through which there must of Necessity go off a much greater Quantity than either by *Stool* or *Urine*, or both together.

*A.* Well, I am wonderfully pleased to know this surprizing Part of Philosophy, and do intend for the Sake hereof to buy *Sanctorius's* Book: But, to go on, pray what is the *Nature* and *Use* of the Intestines?

\* This is upon Trust from Mr. *Leeuwenhoek*, who certainly was very happy at these Kinds of Invention, for his Eyes, though old, and Microscopes, though single ones, could in many Cases discover, what I never could with young Eyes, and the best double Microscopes. I have tried in Variety of Subjects to find these Pores in the *Cuticle*, but in vain. And indeed I very much question whether ever he did actually see any such Thing.

*B.* The



B. The *Intestines* are a long and large Pipe, which, by several Circumvolutions and Turnings, reaches from the *Pylorus* of the Stomach to the *Anus*: They are knit all along to the Edge of a Membrane, called the *Mesentery*, and are six Times as long as the Body to which they pertain: Their Use is, by a peculiar *vermicular Motion* of their spiral-fibred Coats, to convey along, and extrude out of the Body, the *Fæces*, or the *recrementitious Part* of the Food, after the *Chyle* is strained from it.

A. Pray how many different *Organs of Sensation* are there?

B. Four particular ones, *viz.* the *Eye*, for seeing; the *Ear*, for bearing; the *Nose*, for smelling; and the *Tongue*, for tasting: And there is one general Sense, *viz.* of feeling, common to all the Parts of the Body.

A. What is the *Structure* and *Use* of the Eye?

B. The *Eye* is a curious and most wonderful Piece of Nature's Work, admirably contrived with various *Coats*, *Muscles*, *Vessels*, and *Humours* of three several Kinds, for the Purpose of Vision: The first Humour of the Eye is called the *aqueous Humour*, being in all Respects like Water, but of a spirituous Nature; for it will not freeze in the greatest Cold. The second is called the *crystalline Humour*, being transparent, and more solid than either of the other; its Figure resembles an optic Lens, convex on both Sides, and its Use in the Eye is the same. Behind this lies the *vitreous* or *glassy Humour*; it is very much like the *White of an Egg*; is in greater Abundance than either of the other; it gives the Eye its *spherical Form*;  
X and

and is thicker than the *aqueous*, but thinner than the *crystalline Humour*. Next this Humour, on the Bottom of the Eye, is spread a fine curious Membrane, called the *Retina*, through which are expanded the *medullary Fibres* of the *optic Nerve*, which come from the Brain. Now the Rays of Light, which come from all Parts of any Object, falling upon the *aqueous Humour* of the Eye, are through it refracted to the *crystalline Humour*, by which as a *double convex Lens* (kept always at a proper Distance by the *glassy Humour*) they are all converged and united on the *Retina*; the Impression thereof being communicated to the *common Sensory* of the Brain by the *optic Nerves*, doth there present to the Mind the *Species* and Image of the Object; and thus is *Vision performed by Means of the Eye*.

A. Pray how is the Sense of *Hearing* performed by the *Ear*?

B. I have already told you, that Sounds are brought to the *Ear* from the *sonorous Body* by Means of the *Air*; and the external Part of the Ear is so contrived by its Ridges and Hollow, that Sounds, being gathered into the Ear as into a Tunnel, are thereby directed to the *Meatus Auditorius*, through which they pass and strike upon a thin transparent Membrane of an oval Figure, set a little obliquely across the Passage of the Ear; behind this Membrane there is a pretty large Cavity, which, with the said Membrane, from its Resemblance, is called the *Tympanum*, or *Drum of the Ear*: In this Cavity are four small Bones, which from their Form are called *Malleolus*, or the *Hammer*;  
the

the *Incus*, or the *Anvil*; the *Stapes*, or *Stirrup*; and the *Os Orbiculare*, or *circular Bone*. Within the *Tympanum* there are several other Cavities, as the *Vestibulum*, the *Labyrinth*, and the *Cocblea*; these internal Cavities are always full of Air; wherefore the Sounds in the external Air striking on the Drum, move the four little Bones in the *Tympanum*, and these in like Manner move the internal Air, which maketh an Impression on the fine Branches of the *auditory Nerve* spread through the *Vestibulum*, the winding Tubes of the *Labyrinth*, and *Cocblea*; and thus all Refractions and Modulations of the external Air become perceptible, and consequently all the different Sounds they convey become audible, and intelligible to the Mind, by the Communication of these Nerves with the Brain, or *common Sensory*.

A. Pray how is the Sense of Smelling effected in the *Nose*?

B. The Cavity of the *Nose* is divided into two Parts, we call the *Nostrils*, by a Partition, of which the upper Part is bony, and the lower cartilaginous: The upper Part of the Cavity is covered with a thick glandulous Membrane, above which, the *olfactory Nerve* is finely branched out and spread over the Membrane of the spongy Bones of the *Nose*, and the other sinous Cavities of the *Nostrils*: Whence the Exhalations of Odours entering the *Nostrils* make their Impressions on the Fibres of the Nerves, which, by their Communication with the Brain, excite in the Mind the *Smell* or *Sensation of Odours* of every Kind.



*A.* And thus, I suppose, you account for the Sense of *Taste* in the *Tongue*?

*B.* The *Tongue* is covered with two Membranes; the external is thick and rugged, especially in Beasts; the internal Membrane is thin and soft; upon it appear several *Papillæ* or small Risings, like the Tops of the small Horns of Snails; these *Papillæ* are made of the Extremities of the Nerves of the Tongue, and piercing the external Membrane, are constantly affected by those Qualities in Bodies, which have their Tastes excited in the Mind by Means of these *nervous Papillæ*; and thus are these *Papillæ* the immediate *Organ of Tasting*.

*A.* Pray how is the general Sense of Feeling performed?

*B.* Of this a general Account must serve: I have already told you, that from the Brain and spinal Marrow there issue out divers Pairs of Nerves, which are ramified and dispersed through all Parts of the Body; and consequently no Impression on any Point, either on the Superficies, or internal Compages of the Body, can be any way made, but it must immediately affect either the Extremity, or some Part of a Nerve, and is therefore immediately communicated to the Brain by the *animal Spirits*; and thus the Mind becomes conscious of every Motion, Affection, or Accident of the Body; and this we call the *Sensation of Feeling*.

*A.* Having thus obliged me with an Account of the *solid Parts*, and of the *Organs* and *Manner of Sensation*, I beg you would now proceed to describe the *Fluids* of the human Body;

Body ; and first, pray, what do you call the *Chyle* ?

B. The *Chyle* is a milk-like liquid Substance, into which the Food is converted by the *Concoction* and *Digestion* of the Stomach, as before I told you ; the *Chyle* passing by the *Pylorus* out of the Stomach into the first of the Intestines, called the *Duodenum*, in it and in the next, called the *Jejunum*, it mixeth with the Bile and pancreatic Juice ; by which Means the *Chyle* undergoes a further Preparation ; the more alimentary Part being hereby refined and separated, is received into the numerous Orifices of the first *lacteal Veins*, opening into the said Intestines ; by these it is conveyed to, and strained through the Glands of the Mesentery ; whence it is received by a second Sort of lacteal Veins, and carried to the Basen, called the *Receptaculum Chyli* ; where being duly impregnated with the *Lymph* from the *Lymphæducts* there poured into it, it is thence carried upward by the thoracic Duct, and emptied into the left *subclavian Vein*, where it is mixed with the reflux venal Blood, descends into the right Ventricle of the Heart, is thence circulated through the Lungs into the left Ventricle, and from thence through all the Parts of the Body : And this is the *animal Oeconomy*, or ordinary Method by which the *Blood* is removed, and *Life* continued.

A. Pray what is the *Blood* ?

B. The *Blood* is a vital Stream proceeding from the Fountain of the Heart, and circulating constantly through the whole Body by the Canals of the Arteries and Veins. If it be viewed

with a *Microscope*, it appears to consist of small red Globules swimming in a thin transparent Serum, and that each Globule is made up of six lesser ones, which, resolved, take upon them the Nature of the *Serum*, whose Colours are various. Dr. *Boerhaave* says, that the *Mixture, Fluidity, Heat, and Redness* of the *Blood*, are owing to, and preserved by the *circulatory Motion* thereof.

*A.* Pray what is the Rate of the Blood's Motion through the Body?

*B.* Each Ventricle of the Heart will contain about *an Ounce* of Blood; the Heart contracts about 4000 Times in an Hour; hence there passeth through the Heart every Hour 4000 Ounces of Blood, which is 250 lb. Weight. Now an Ounce of Blood is equal in Bulk to  $1\frac{66}{1000}$  Inch; and if we suppose the Heart contracts 80 Times in a Minute, then 80 Ounces of Blood will be equal to  $132\frac{72}{1000}$  Inches, which passeth the Heart in one Minute. Now Dr. *Keill* found the Diameter of the *Aorta* to be 0.73 Parts of an Inch, and thence its Orifice 0.4187; by which divide  $132\frac{72}{1000}$ , and the Quotient will be the Length of the Cylinder, or Space through which the Blood will move in a Minute, *viz.* 316 Inches, or 26 Feet. But, because of the *Diaστοle* of the Heart which takes up half the Time of a Pulsation, there goes out of the Heart 80 Ounces in half a Minute; whence the Blood's Velocity will be double, or it moves at the Rate of 52 Feet in a Minute.

*A.* Is the Velocity through the Trunk the same as through all the Branches taken together?

*B.* No;



B. No; for the same ingenious *Anatomist* found the exact Proportion of the Branches to the Trunk of the Artery to be as 12387 to 10000, and consequently the greatest Velocity of the Blood will be to the least, as 5233 to 1; or the Blood moves 5233 Times slower, in some capillary Arteries, than it does in the *Aorta*. The Blood is received from the Arteries into the Veins, where it still moves slower as it approaches the Heart. Now the Arteries are to the Veins, as 324 to 441; and therefore the Blood moves in the Veins above 7116 Times slower than in the *Aorta*.

A. What Quantity of Blood do you find to be in the *human Body*?

B. You ask a Question very difficult to be answered: At present I cannot find any Person can certainly tell; *Authors* determine from 10 to 25 lb. and Dr. *Keill* reckons the whole Body consists of near two-thirds Fluids, the greatest Part of which is Blood.

A. What do the *Chymists* find the Blood to consist of?

B. Of much *volatile Salt*, and *Spirits*; some *Pblegm* and *Sulphur*; a little *Earth*; and but little or no *fixed Salts*: *Alkalies* dissolve in it, and *Acids* coagulate it.

A. How are the other *Fluids of the Body* produced?

B. They are all separated from the Blood in some Part of the Body or other by the Glands. Thus the *Saliva* or *Spittle* is secreted by *parotidial Glands* behind the Ears, and *maxillary Glands* of the Mouth; the *Bile* is separated by

the Liver; the *Milk* is strained off from the Blood by the Gland of the Breasts; the *Lymph* is a fermenting Liquid secreted by the small conglobate Glands in several Parts; the *Semen* is secreted from the Blood by the Testicles, brought thither through various Circumvolutions and Contortions of the *spermatic Arteries*; the *Pancreas*, or *Sweet-bread*, also separates a sweet lymphid Liquor or Juice, to dilute and refine the *Chyle*; the *Urine* is secreted by the Reins; it contains *volatile Salt*, *Spirit*, an *oily Sulphur*, *Phlegm*, and *Earth*; from *Urine* fermented is distilled that luminous Matter called *Phosphorus*, which is either solid or liquid. *Phlegm* is a mucous Matter, separated by the Glands of the Mouth, Nose, &c. *Serum* is the aqueous Part of the Blood, which is not discerned from the Blood itself in the Body; but taken out, it separates from the coagulated Blood, by the Action of the Cold; the *aqueous Humour* of the Eye, secreted from the *arterial Blood* in the Vessels of the Eye; the *crystalline* and *vitreous Humours* are improperly so called, they consisting of an infinite Number of small Vessels filled with circulating *Fluids*.

*A. Sir*, I am greatly obliged to you for taking so much Pains for my Information, yet, as you seem to do it with a great deal of Pleasure, I shall be bold to ask a few Questions more; and, pray, what do you say of the *Nature of Hair*?

*B.* When we examine the *Hairs* with a *Microscope* (saith Dr. Keill) we find they have each a round bulbous Root lying pretty deep in the Skin,

Skin, and which draw their Nourishment from the surrounding Humours; that each Hair consists of five or six others wrapped up in a common Tegument or Tube: They grow as the Nails do, each Part near the Root, thrusting forwards that which is immediately above it; and not by any Liquor running along the Hair, in Tubes, as Plants grow. Their different Colours depend on the different Quality and Temperament of the Humours producing them; they serve for the Covering and Ornament of the Body. Mr. *Derham* gives us the Representation of two Hairs of a Mouse (the most transparent of any) the one in *Fig. L.* on *Plate XV.* fronting *p.* 307, where *a* is its Appearance through a small Magnifier, and *A* as it appears through a large one. *Fig. LI.* on the same Plate, *c* and *D* are the same Views of another Hair, to shew the different internal Make of the Hair of the same Animal\*.

*A.* Pray what are the *Nails*?

*B.* Our *Nails* are of the same Nature as the *Hoofs of Beasts*; and are nothing but the Covers or Sheaths of *Papilla Pyramidales* of the Skin on the Extremities of the Fingers and Toes, which dry, harden, and lie close upon one another.

*A.* You have been long telling what those Parts are of which our Bodies consist; but,

\* I never could find, by viewing of transparent Hairs, that they afforded any other Appearance than that of *clear, long, round, or cylindrical Tubes*; the Hollowness of the larger ones being very visible, but of the smaller ones not discernible; and their Texture or Substance has always appeared to me to be simple or uncompounded. So that the Reader is to *believe* or *reject* what Dr. *Keill* and Mr. *Derham* have asserted, as he may think reasonable.

pray,



pray, how are our Bodies at first generated or formed in the *Womb*? This you have not yet told me.

B. The Learned of late have found by their *Microscopes*, that not only Man, but all Animals, do really exist (in their proper Form compleat in all their Parts) in the Seed of the Male Animal, before Generation, in a small invisible State, called *Miniature*. It is amazing to see the prodigious Number of little Creatures, like so many Tadpoles, swimming every Way in the Male Sperm of all Animals. Those Animals are so small, that 3000000000, *i. e.* three thousand Millions of them, are not equal to a Grain of Sand, whose Diameter is but the 1000th Part of an Inch. The *Animalcule* that has the good Luck to get safe into the *Womb*, through the *Fallopian Tubes* in a Kind of Egg, is there fostered a while some how, 'till, at length, the *Placenta* appears like a little Cloud on one Side of the external Coat of the Egg; and at the same Time the Spine of the Embryo is grown so big as to be visible, and a little after, the *Brain* and *Cerebellum* appear like two small Bladders, and the Eyes next stand goggling out of the Head; then the *Beating of the Heart*, or *Punctum Saliens*, is plainly to be seen, and the Extremities of the Body discover themselves last of all; so far Dr. Keill: And this is the present *Theory of Generation*; and very much alike in *Plants* and *Animals* \*.

A. Pray

\* The Affair of *Impregnation* and *Generation*, even after all the late Discoveries, remains so very perplexed, obscure, and doubtful, that nothing of Certainty can yet be determined about it. Some asserting the *little Animal* to be originally in the Female's Egg; others deny that, and affirm they have no Being there till the Egg

A. Pray what do you observe in particular of the Nature of Beasts \* ?

B. The

is fecundated by the *Semen Masculinum in Coitu*. See the Controversy in Mr. Bradley's Phil. Account of the Works of Nature, Chap. 9. *Miscellanea Curiosa*, Vol. I. Page 142. by Mr. Garden.

\* 1. Mr. Ray, in his *Synopsis of Animals*, distinguishes *Quadrupeds* into two Kinds, viz. (1.) The *ungulated* or *hoofed* Beasts with four Feet; and (2.) The *unguiculated*, *digitated*, or *clawed* four-footed Animals.

2. The *Hoofed Quadrupeds* are either (1.) *Solidipedes*, or Whole-hoofed; as the Horse, Ass, Mule, &c. Of this Tribe none bears Horns. (2.) *Bifulcated*, or Cloven-footed: Of these, some are *Ruminant*, or *chew the Cud*; as the Ox, the Sheep, the Goat, the Deer Kind. Of these the three former bear *hollow* and *perpetual Horns*; the latter, *close* and *deciduous* Horns. Again, some of the *Cloven-footed* do not *chew the Cud*, as the Hog and Swine Kind. (3.) *Quadrupeds* which have their Hoof cloven into four Divisions, and seem not to be *Ruminant*; as the *Rhinoceros*; the *Hippopotamus*, or *River-Horse*; the *Tapijerote*, and *Capy-Bara* of *Brasil*, &c.

3. Of the second or *unguiculate* Kind of *Quadrupeds*, the *Elephant* is somewhat singular; his Claws adhere to each other, and are all covered with one common Skin, having only their obtuse Nails sticking out round the Margin of the Foot.

4. The *Camel* and *Dromedary* have only *two Claws*; and, though they have no Horns, they *ruminate* or *chew the Cud*, and have the four Stomachs of horned ruminant Animals. Of these some have one *Bunch* on the Back, and another Sort have two.

5. The *Anthropomorpha*, or those *Quadrupeds* which have the Foot divided into many *Claws*, with broad Nails on them, like the Fingers and Toes of Men, make the third Species of this *unguiculate* Kind: As *Apes*, which have no Tails, and *Monkeys* which have Tails, and they of a large Size, called *Baboons*. To this Tribe also belong the *Ourang-Outang*, or the Wild Man; the *Caqui* and *Cay* of *Brasil*; and the *Cercopitbeci*, or Monkeys of several Countries.

6. A *fourth Species* of this Kind is when the Claws are many, and have crooked and sharp-pointed Nails, like the Talons of Birds of Prey; and they are of the *Cat*, the *Dog*, the *Vermin*, and the *Hare Kind*.

7. Of the *Cat Kind* of *Quadrupeds*, are reckoned the *Lion*; the *Tiger*; the *Pardalis* (whose Male is *Pardus*, Female *Panther*); the *Leopard*; the *Lynx*; the *Cat-a-Mountain*; the *Bear*; and the common *Cat*.

8. Of the *Dog Kind* they account the common *Dog*, the *Wolf*, the *Fox*, the *Jackall*, the *Civet Cat*, as it is erroneously called; the

*Rackoon*,

*B.* The Nature of *Beasts*, or *Quadrupeds*, is, with Respect to the sensitive Life, or animal Oeconomy, the same with that of Man already described: What I shall here take Notice of then, shall be those Particulars wherein the Brute differs from a Man, and is what he is; the Chief of which are the following: 1. Their external *Form* and *Shape*, which is almost infinite; and is

*Rackoon*, or *Ratoon*; the *Badger*; the *Otter*; the *Sea Calf*, or *Seal*; the *Sea Horse*; the *Sea Cow*; and some other outlandish Animals.

9. Of the *Vermin Kind* are the *Weasel*; the *Ermine*, or *Stoat*, if white; the *wild Stoat*, or *Ferret*; the *Pole Cat*; the *Marten*, or *Maxtlet*; the *Sable*; the *Genetta*; the *Ichnuemon Bellonii*; the *Indian Mungo*; and *Quirpele*, &c.

10. Of the *Hare Kind* are the *Hare*; the *Rabbit*, or *Coney*; the *Porcupine*; the *Bever*; the *Squirrel*; the *Rat*; the *Mouse*; the *Dormouse*; the *Guinea Pig*; the *Tapeta*, *Aperca*, *Agati*, and *Paca*, of *Brasil*; and the *Conies* and *Mice* of various foreign Countries.

11. To these Kinds of *Quadrupeds* may be added some others more anomalous, as *Viviparous four-footed Animals*, having a longish *Snout*, and their *Feet* divided into many *Claws* or *Toes*, and having *Teeth*: As the *Urchin*, or *Hedge Hog*; the several Sorts of *Tatons*, or *Armadillo's*; the *Mole*; the *Shrew-Mouse*; the white *Indian Erinaceus*, &c.

12. Others, which have a longish *Snout*, their *Feet* divided into many *Claws*, but have no *Teeth*: As the great and lesser *Ant-Bear*; the *Tamandua Guacu* of *Brasil*, &c.

13. *Flying Quadrupeds*, with a shorter *Snout*, and their *Feet* divided as before; as all of the *Bat-Kind*, or *Flutter-Mice*; of which there are several *Sizes*, and different *Forms*.

14. *Viviparous* and *sanguineous Quadrupeds*, breathing with *Lungs*, and having only one *Ventricle* in the *Heart*; as the *Frog*; the *Toad*; the *Tortoise*; of these there are many different *Species* both of *Land* and *Water* ones in foreign *Parts*.

15. *Oviparous Quadrupeds* with a long *Tail* stretched out horizontally; as all of the *Lizard Kind*; the *Crocodile*; the common *Eft*, or *Newt*; the *Seps*, a Sort of footed *Serpent*; the *Salamander*; the *Camelion*; a flying *Lizard*; with various other *Kinds*.

Consult Mr. Ray's *Synopsis Animalium*. *Johnstoni Historiæ Naturalis*. *Borelli de Motu Animalium*. *Willis de Anima Brutorum*. *Aristotle* and *Ælian* among the *Ancients*; as also *Pliny's Natural History of the World*.

that



that which chiefly distinguishes the various Species of Brutes. 2. Their Size, of which there are numerous Degrees; the greatest of all are the *Elephant* and *Rhinoceros*. 3. Their *prone Posture*, necessary to their Way of Living. 4. Their *Motion*, or *Gait*, which is on *four Legs*, and are therefore called *Quadrupeds*. 5. The special Contrivance and Form of their *Heads*, which is infinitely various. 6. They are some of them endued with *Horns* of various Figures and Sizes. 7. They have a special Form and Structure of their *Ears* externally. 8. The Make of the *Eye* is very different in different Species of Animals. 9. The *Neck* is adapted to the Length of their Legs, except only in the *Elephant*, which hath his *Proboscis*, or Trunk, to supply that Defect. 10. The Form of their *Legs* is peculiar, yet different in divers Species; whence the slow Motion of some, and wonderful Agility and Swiftnefs in others. 11. They are all provided with *Tails* of different Length, Size, &c. whose Use is to defend themselves from the Molestation of Flies, &c. 12. Their Bodies are clothed with various *Teguments* of *Hair*, *Wool*, *Spines*, *Down*, &c. suitable to their particular Occasions of Life. 13. Their *Feet* are, some cloven into *Hoofs*, others divided into *Claws*, with Variety of different *Nails* to answer their various Purposes of Life. 14. Their *Nostrils* are somewhat differently formed from ours, and from one another. 15. Their *Brain* is considerably less in Proportion to their Bodies, than Man's. 16. They have some of them a peculiar Membrane, called the *nictitating Membrane* of the Eye, by which the Eye, frequently

quently winking and contracting the Pupil, is preserved from the Annoyance of the Grass, Stubble, &c. in gathering their Meat. 17. They are provided with a strong, tendinous, and insensible *Ligament*, braced from the Head to the Middle of the Back, called the *white Leather*, which suspends the weighty Head without Pain, in grazing, &c. 18. The *Stomachs* of Brutes are different from ours, and from each other's, both in *Size* and *Number*; for some have *small*, others *large Stomachs*; in some, *one* only; in others, *two* or more; thus the *Dromedary* hath *four Stomachs*. 19. Some have the wonderful Faculty of *Rumination*, or chewing the *Cud*; for the compleat Mastication of the Food at the resting leisure Times of the Animal. 20. The *Hearts* of Animals are of special Structure; in some it hath but *one Ventricle*, as *Frogs*; in others *two*; and in some *three Ventricles*, as in the *Sea-Calf*, &c. 21. Some Animals live only on *Land*; others, called *Amphibious*, live both on *Land* and in the *Water*. 22. The *Food* of Brutes is very various, some feeding on *Flesh*, called *Carnivorous*; others on *Grass*, called *Graminivorous*; some on *Grain* and *Seeds*, called *Granivorous*, &c. Besides innumerable other Differences that might be named, of less Note, between a *Man* and a *Brute*.

*A.* Please now to oblige me with a short Account of the *Nature of Birds* or *Fowl* \*.

*B.* The

\* 1. *Birds* are either *Land Fowl*, or *Water Fowl*: Of *Land Fowl*, some have crooked Beaks and Talons; of these some are *carnivorous*, and *rapacious*, being called *Birds of Prey*; some *frugivorous*, or which feed on Corn, and are called by the general Name of *Parrots*. 2. Of

B. The Philosophy of Fowl, or the feathered Tribe, is really wonderful, as will appear from a short

2. Of *Birds of Prey*, some are *diurnal*, preying in the Day-time; and of these they reckon a greater and a lesser Sort: The greater are either of a more bold and generous Nature, as the *Eagle-kind*; or of a more cowardly and sluggish, as the *Vulture*.

3. The lesser *diurnal Birds of Prey*, are the *Accipitres*, or of the *Hawk-kind*. And these are of a more bold and generous Nature, and are wont to be reclaimed and managed for Fowling, and are called *Hawks*: These the *Falconers* distinguish into *Long-winged*, as the *Falcon*, *Lanner*, &c. and *Short-winged*, as the *Goshawk* and *Sparrow-Hawk*.

4. Those of the *Hawk-kind*, which are of a Nature more cowardly and sluggish, or else indocile, are neglected by the *Falconers*, and so live at large. And of these there is also a greater Sort, as the *Buzzard-kind*; and a lesser, as the *Butcher-Bird*, or *Srike*; (about as big as a *Black-bird*) and the *Bird of Paradise*, which is exotic.

5. Of *Birds of Prey* with crooked Beaks and Talons, some are nocturnal, or which fly and prey by Night, as the *Owl-kind*. And these are either horned or eared, as the *Eagle-Owl*, the *Horn-Owl*, &c. or without Horns, as the *Brown-Owl*, the *Grey-Owl*, &c.

6. There is a Sort of *Land-Birds*, which feed on both *Flesh* and *Fruits*, and are distinguished into three Sorts, according to their Bigness; the greatest Size being called *Maccaws*; the middle-sized, and most common, *Parrots* and *Propinjays*; and the least Sort, *Parakeets*; and all this Kind make use of their Beak in climbing, and move the upper Jaw.

7. *Land-Birds* that have their Bill and Claws more straight, are also divided into three Sizes. The greatest Sort are such, as by Reason of the Bulk of their Bodies, and the Smallness of their Wings, cannot fly at all; these are exotic Birds of a singular Nature, as the *Ostrich*, the *Cassware*, the *Dodo*, &c.

8. The middle-sized Kind are divided by their Bills into such as have large, thick, strong, and long ones; some whereof feed promiscuously on *Flesh*, *Insects*, and *Plants*; as the *Crow-kind*, which are wholly black; and the *Pye-kind*, which are party-coloured. Some feed on *Flesh* only, as the *King's-Fisher*; and some on *Insects* only, as the *Wood-pecker*. And into such as have a smaller and shorter Bill, whose Flesh is either white, as the *Poultry-kind*; or blackish, as the *Pigeon* and *Thrush-kind*.

9. The least sized Kind of *Land-Birds*, with straight Bills and Claws, are called *Small Birds*; and these are of two Kinds, viz. *soft-beaked*, which have slender, straight, and pretty longish Bills, most of them, and feed chiefly on *Insects*; or *hard-beaked*, which have thick and hard Bills, and feed mostly on Seeds.

10. *Water-*



a short Survey thereof: For, 1. with respect to their *Generation*, they are produced from *Eggs*, and are therefore called *oviparous Animals*. 2. Their *Motion* is two-fold, *viz.* *flying* and *walking*; and are thereby rendered, 3. the Inhabitants both of the *Land* and *Air*: For which Purpose, 4. they are wonderfully contrived with a

10. *Water-Fowl* are such as frequent *Water* and *watery Places* to seek their Food; and these are all cloven-footed, and generally have long Legs, naked above their Knees, that they may the more conveniently wade in Waters. Of these they reckon two Sorts, *viz.* a greater, as the *Crane*, *Jabiru*, &c. and a lesser, which are either *Piscivorous*, feeding on Fish, as the *Heron*, *Spoonbill*, *Stork*, &c. or *Mudsuckers* and *Insectivorous*, of which some have very long and crooked Bills; as the *Curlew* and *Wimbrell*; and others long and straight, as the *Woodcock* and *Godwit*.

11. Others have middle-sized Bills, as the *Sea-pye* and *Red-shank*; and a third Sort have short Bills, as the *Lapwing* and *Plover*. Those are reckoned *short Bills*, which exceed not an *Inch and a Half*; the *middle-sized Bills* are betwixt that and two Inches and a Half; and *long Bills* are all above two Inches and a Half.

12. Another Kind of *Water-Fowl* swims in Water; some of which, as the *Marehen* and *Coot*, are *cloven-footed*, and most are *whole-footed*. And of these, some few have very long Legs, as the *Flamant*, the *Avogetta*, and *Corrija*; but mostly they are short-legged; of which some few have but three Toes on a Foot, as the *Penguin*, *Rasorbill*, &c. but generally they have four Toes on a Foot; and these either all connected together by intervening Membranes, as in the *Pelican*, *Solan-Goose*, or more usually with the back Toe loose.

13. And this Kind are either *narrow-billed*, or *broad-billed*; those with narrow Bills have them either blunt or hooked at the Top, of which Sort some are *ferrate*, as in the *Diver* Kind; and some not *ferrate* or *toothed*, as in the *Puffin*; or sharp-pointed or straighter, of which Sort some have long Wings, as the *Gull* Kind; and some shorter, as the *Diving Birds*, called *Douckers*.

14. Those with *broad Bills* may be divided into the *Goose* Kind, which are larger; and the *Duck* Kind, which are smaller; and these latter into *Sea-Ducks*, and *River* or *Pond-Ducks*.

15. Most *Water-Fowls* have a short Tail; and none of this Kind have their Feet disposed like *Parrots* and *Woodpeckers* that have two Toes forward, and two Toes backward, none having more than one back Toe, and some none at all.

*Pair*

*Pair of Wings* to buoy themselves up in the fluid elastic Sphere of Air, and whereby they keep their Bodies on a due Balance and Equipoise in their Motion. 5. The *Tails* of Birds are given them to steer their Course, keep them steady in Flight, and to assist them in their Descents and Ascents into the Air. 6. The *Plumage* of Birds is a wonderful Thing, their Feathers cloath and beautify them; a Feather is a curious Production in every Part, the *Quill*, the *Rib*, and the *Vanes*, being thoroughly understood: The Pith in the *Rib* appears through a *Microscope* on the transverse Section *a*, as is represented in A, Fig. LII. on Plate XXV, fronting p. 307. And a *Vane* of a Feather (as *b*) appears like another Feather when magnified, as in B, Fig. LIII. on the same Plate, where you observe the net-like Texture of its membranous Part, and C is the little End magnified. 7. The *Feet* of Fowl are very particular, being spread some with Membranes for swimming, as *Ducks*, *Geese*, &c. some without for steady walking, perching, holding their Prey, &c. 8. The terrible sharp-pointed *Talons* in Birds of Prey are very remarkable, as those of the *Eagle*, *Vulture*, &c. 9. The *Heads* of Birds are admirably suited for making Way through the Air, being very near the Figure of Sir *Isaac Newton's* Solid of least Resistance. 10. The *Beak*, or *Bill*, is a strange Piece of Art, their very Jaw-bones, as it were, growing out of their Head, and meeting in a Point, wonderfully adapted to pierce the Air, gather Food, and penetrate Wood, Earth, &c. for Prey. 11. The *Ears* stand not out from the Head to hinder Flight. And, 12. The commodious Si-

tuation of the Eyes of *Birds* is surprizing ; for each of their Eyes takes in very near an *Hemisphere*, and consequently with both Eyes they can see nearly all around them at once, and so the better seek their Food and escape Dangers. 13. The wonderful *Structure of the Body* of Fowls, in the Form of a Ship, the *Breast-bone* serving as a Keel, and their Tails as Rudders, to govern them in their *aerial Voyages*, deserve our Attention and Admiration. 14. The *internal Make of their Bodies*, and the several Parts, as the *Larynx*, the *Tongue*, the inner *Ear*, the various *Muscles*, their *Lungs*, the Posture of the *Heart*, &c. are different for the most Part from other Animals. 15. The *Migration* of Birds is an Instance of great Amazement: The Stork in the Heaven knoweth מועדיה *her appointed Times*, and the Turtle, and the Crane, and the Swallow, *observe the Time of their Coming*, saith God himself, *Jer. viii. 7.* What strange *Instinct* should induce them to change their Place? What should direct some to warmer Climes? others to colder Climes? Yea, what should incline Swallows, for Instance, to take up their *Winter Quarters* in the Water, under the Ice, in Lumps and Clusters in the frozen *northern Seas*? as it is well known they do \*. 16. The *Incubation*

\* Since not only *Olaus Magnus* reports this in his *Breviar. Hist. Serpent.* Lib. XIX. Cap. 11. but also *Etmuller* affirms he has found Swallows in this Condition among the Reeds of a *Fish-Pond*; and the Rev. Mr. *Derham* says, that at a Meeting of the Royal Society Feb. 12, 1711-12, Dr. *Colas* declared he saw 16 Swallows so drawn out of the Lake of *Samdrot*, and about 30 out of the King's great Pond in *Rosincilin*; and that at *Schlebitten*, near an House of the Earl of *Dohna*, he saw two Swallows just come out of the Waters, that could scarce stand, being very wet and weak, with their Wings hanging on the Ground; and that he hath observed the Swallows to be often weak for some Days after their Appearance.



of Fowls is worth our Notice : How (says the great *Naturalist*, the Rev. Mr. *Derham*) should they be aware that their Eggs contain their Young? or, that their Production is in their Power? 17. Their *Nidification* ought to humble the Pride of Man; with what inimitable Art, Neatness, and Propriety, do they contrive and build their *Nests*? 18. The *Egg* itself is a stupendous Contrivance of infinite Wisdom. Most Animals are produced from Eggs *within*; but Fowl exclude their Eggs, which therefore are made with hard crusty Shells to preserve the included *Embryo* from Accidents, and to contain suitable Nourishment for it : Chickens are nourished by the White alone till grown great, and then feed on the stronger Diet of the Yolk. 19. Though all Fowl are hatched from Eggs; yet it is not always by the Incubation or Brooding of the parent Fowl, but by some other Heat or Warmth sometimes: Thus, *Job xxxix.* (the *Ostrich*) *leaveth her Eggs in the Earth, and warmeth them in the Dust*; and at this Time they hatch Chickens in Ovens at *Grand Cairo* in *Egypt*; each Oven containing 80000 Eggs. 20. Some Birds feed on Grain; and are called *Granivorous*; and Birds of Prey are called *Carnivorous*, because they feed on Flesh. These are a few of the many wonderful Properties of the *Nature of Birds*.

A. Indeed, Sir, it affords me unspeakable Pleasure to hear you recount the Particulars of the wonderful Nature of different Animals; and, pray, go on if you please, in the next Place, with the *Nature of Fishes* \*.

B. The

\* i. *Aristotle* divides Fishes into three Kinds, viz. *Cetaceous*, *Cartilaginous*,

B. The remarkable Particulars in the Survey of the *Nature* of Fishes, which I shall just observe

*Cartilaginous*, and *Spinous*; and to this Division Mr. *Willoughby* consents, as better than that of *Rondeletius*, who distinguishes Fishes into *Sea-Fish*, *River-Fish*, *Pond* or *Lake-Fish*.

2. The *Cetaceous* Kind, sometimes called the *Bellæ Marinae*, have Lungs, and breathe like *Quadrupeds*; they copulate also like them, conceive and bring forth their Young alive, and suckle them with their Milk.

3. The *Cartilaginous* Sort are produced from large Eggs like Birds, which are excluded the Womb also, like those of Birds.

4. The *Spinous* Kind are also *Oviparous*, but their Eggs are smaller; and they have *Spinæ*, or sharp Bones up and down in their Flesh to strengthen it.

5. But Mr. *Willoughby* thinks it would be yet more proper to distinguish Fish into such as breathe with Lungs, and such as breathe with Gills; and then to subdivide those that breathe with Gills into *Viviparous*, and *Oviparous*.

6. The *Viviparous* Kind he subdivides into the long, as the *Sharks* and *Dog-Fish*; and broad Kind, such as the *Pastinaca*, *Rajæ*, *Squatinae*, &c.

7. The *Oviparous* Kind are the most numerous; and these he subdivides into the *Flat-fish* Kind, and such as swim with their Backs upright, or at right Angles to the Horizon. He gives us the following Catalogue of our *English Fishes*.

8. Of the long *Cartilaginous* Kind, are the white and blue Shark; the *Tope*; the *Prickled Dog*, or *Hound-Fish*; the *Smooth-Hound-Fish*; the *Cornwall-Bounce*; the *Morgay*, or *Lesser Hound-Fish*.

9. Of the plain *Cartilaginous* Kind, are the *Scate* or *Flare*; the *Thornback*; the *White-Horse*; the *Angel*, or *Monk-Fish*; the *Toad-Fish*, or *Sea-Devil*.

10. Of the plain *spinous* Kind, are the *Turbet*, or *Bret*; the *Cornwall-Lug-Alefe*; the *Plaice*; the *Dab*; the *Flounder*; *Fluke*, or *Butt*; the *Holy-Butt*, or *Turbot* of the North; the *Sole*.

11. Of the *Eel* Kind we have the *Lamprey*; the *Lampern*; the *Conger-Eel*; the common *Eel*; the *Sand-Eel* or *Lance*; the *Butter-Fish*; the *Sea-Loach*; the *Eel-Pout*, or *Turbot*; the *Sea-Wolf*; the *Sea-Lark*; the *Crested-Sea-Lark*; the *Liparis* of *Rondeletius*; the *Miller's-Thumb*; the *Dutch-Poto-Hogs*.

12. Of the Kinds of Fish wanting the *Belly Pair of Fins*, we have the *Sun-Fish*; the *Acus* of *Aristotle*; the *Sea-Adder*; the *Saw-Fish*; to which may be added the *Mermaid*, or *Syren*.

13. Of the *Non-spinous* Kind with three unprickly soft Fins on the Back, we have the *Cod Fish*; the *Whiting-Pollock*; the *Cole-Fish*; the *Whiting-Blands*; the *Haddock*; the *Whiting*.

14. Of the *Non-spinous* Kind with only two soft Fins on the Back, are the *Hake*; the *Ling*; the *Tunny*, or *Spanish-Mackerel*; the *Grayling*, or *Umber*; the *Ginnard*; the *Schelly*; the *Salmon*;

serve to you, are the following: 1. As they were originally made out of the *Water*, so that is the only Element in which they can live: And therefore, because, 2. Their Motion is *swimming*, they need no Legs, and so have none. 3. Instead thereof, they are much better provided with *Fins*, and more especially a proper Sort of Tails, which serve as *Oars* to waft themselves about withal in the *Water*: For, 4. The *Fins* on the Belly principally serve to keep them from turning on their Backs, as being the heavier Part; as they would do, were those *Belly-Fins* cut off. 5. The Fishes use *Respiration* in *Water*, by passing it through their *Mouths* and *Gills*; for their *Gills* serve in them the Office of the Lungs in other Animals. 6. The Bodies of Fishes are contrived with such divine *Geometry*, as

the Samlet, or Braulin; the Gray; the Salmon-Trout; the Scurf, or Bull-Trout; the Trout; the Red-Chare; the Gilt-Chare; the Smelt; the Rock-Fish, or Sea-Gudgeon; the Lump, or Sea-Owl; the Dog, as it is called in the West of Eng'land.

15. Of the Non-spinous Kind with only one Fin on the Back, we have the Herring; the Pilchard; the Shad; the Sprat, (which is only a young Herring); the Gar-Fish; the Sturgeon; the Pike, or Jack; the Carp; the Bream; the Tench; the Oerwe; the Chub; the Barbel; the Dace; the Roach; Bleak; Gudgeon; Loach; and Minnow. Note, the last twelve of these are called (*Malacostomi*) Leather-mouthed Fishes, because they have no Teeth in their Jaws, but only deep down in their Mouths.

16. Of the spinous Kind with two Fins on the Back, of which the foremost is *aculeate*, or prickly, we have the Basse; the Mullet; the Grey-Garnard; the Tub-Fish; the Rotchet; the Piper; the Sur-Mullet; the Spider; the Scud; the Perch; the Dorge.

17. Of the *aculeate* Kind with only one Fin on the Back, whose Raddi are some prickly, and some soft, we have the Gilt-Head; the Old-Wife; the Ruff; the Prickle-Back, or Bansticle; the lesser Prickle-Back.

18. Of the Cetaceous Kind, there are reckoned only the *Balena Britannica* of the Ancients, at this Time not known; the common Whale; the Dolphin; and the Porpuss.



to pass through the dense *Medium* of Water with the greatest Ease, and the least possible Resistance from it. 7. How wonderously are they defended, beautified, and rendered more apt for gliding through the Water, by those hard, smooth, polished, numerous *Scales*, with which the Surface of their Bodies is so curiously overlaid? 8. The great *Author of Nature* has contrived the *Eye* of Fishes justly suitable to the Nature and Refraction of Water, different from that of Air, for their Eyes are flat outwardly, and not protuberant, lest they should wear and hinder Motion; but the *crystalline Humour* is made *spherical*, and not *lenticular*, or flattish, as ours, who live and see through Air. 9. Fish are contrived with an *Air-bladder*, which makes them buoyant; and according as they dilate or contract their Bladder, by the Means of Air, so they are enabled to abide higher, descend lower, or remain in what Part of the Waters they please. 10. Some Fishes are wonderfully formed with Instruments of Defence, Provision, &c. What amazing circular Rows of *horrible Teeth* fill the Mouth of a *Shark*? other some are endued with *Wings*; some have two or more Feet, as the *Male Whale*, &c. See the wonderful *Unicorn-Fish* in Fig. LIV. on Plate XXVI, fronting p. 342, whose Horn is 10 or 12 Feet in Length. The *Sword-Fish* in Fig. LV. and the *Saw-Fish* in Fig. LVI. on the same Plate, are very surprizing; the *Sword* and *Saw*, where they shoot from the Head, being six, eight, or ten Inches wide, and about five or six Feet in Length, as I remember to have seen them; the Teeth of the *Saw* at the broad  
End

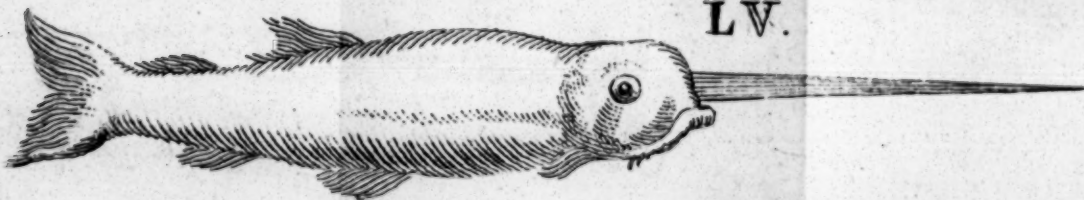
To front Page 342.

Plate XXVI.

Fig: LIV.



LV.



LVI



Fig: LVII

Page 347. Chrysalis.



Cruca.

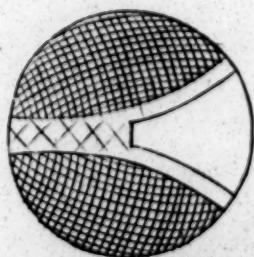
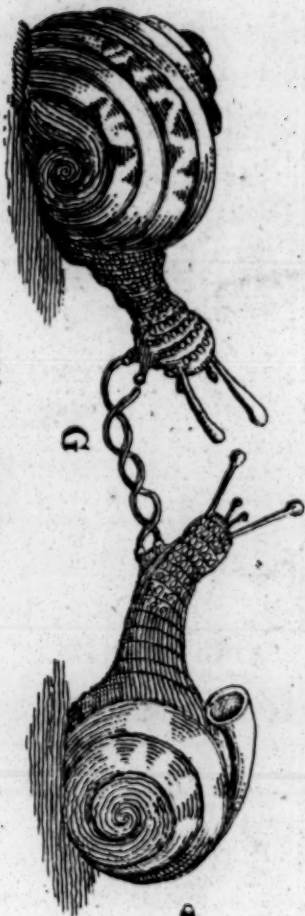
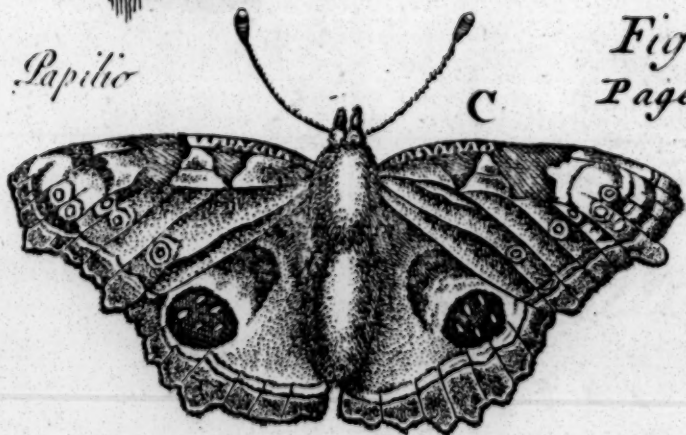


Fig: LVIII  
Page 347

Fig: LIX.  
Page 357.



Papilio







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End being as long as one's Finger. 11. The Size of Fish, and other Water Animals, is almost infinitely different; the greatest is the *Whale*, (called *Leviathan* in Scripture) being the biggest of all. *Pliny, lib. ix. cap. 3.* mentions some Whales 960 Feet in Length; and, *lib. xxxii. cap. 1.* he mentions *Whales* 600 Feet long, and 360 broad, which came into a River of *Arabia*. 12. The Species or Sorts of Fish are as various as their Size, and cannot be all known. I could, had I Time, have named to you a far greater Number of remarkable Peculiarities in the Nature of the finny Tribe: But, if you desire a farther Account, you may consult the voluminous Writings of the Learned.

A. Sir, this is abundantly better than none; pray proceed to recapitulate some of the chief Things observable next, in the Nature of Insects, if you please \*.

B. Nothing

\* 1. Mr. Ray, in his Method of Insects, distinguishes Insects into two general Kinds, viz. such as change their Form, and such as do not change their Form.

2. Insects, which change not their Form, have some six, some eight, some fourteen, others twenty-four Feet, and some many more, which are therefore called *Polypodes*, or *Multipedes*.

3. Those that have but six Feet, are *terrestrial* or *aquatic*; the terrestrial are of various Sorts, as the *Louse*, the *Flea*, the *Cra'-Louse*, the *Wall-Louse*, the *Tick*, and several others found in the rotten decayed Wood of Trees, old Books, in Meal, in the Earth, in Flowers, &c. Those in Water, are a Sort of Louse adhering to Fish; and the *Squilla fluviatilis*.

4. Insects with eight Feet are either with a Tail, as the *Scorpion*; or without, as the *Spider*. Of this Sort some spin no Web, have but two Eyes, and very long Leg, as the *Carter* or *Shepherd*. Others spin a Web, and have many Eyes, and are of divers Sorts. To this Tribe of eight-footed Insects belong several Sorts of Ticks, and the *Syrones*, or *Mites*.

5. Insects not changing Form, and with 14 Feet, are the *Arselli*, or those of the *Wood-Lice*, or *Chefs-bob* Kind, of which some live

B. Nothing pleases me more ; therefore with regard to *Insects*, I observe, 1. That though they

in Water, some on Land. To this Tribe are also referred a Sort of *Water-Gnat*, or *Fly*, and a *Water-Louse*, found upon Fish.

6. Those which have 24 Feet, have the eight fore Feet lesser, and the 16 hinder ones larger. Of these there are two Kinds observed, both with long Bodies ; one larger and of an obscure Colour, among the Rocks by the Sea-side ; the other of a Silver Colour, found in Houses.

7. There is a Kind with 30 Feet, of an oblong Shape, Chestnut Colour, and full flattish Body, usually lying under Logs and Trunks of Trees : It is very agile and swift.

8. The *Multipede* Insects, which change not their Form, are found both in Land and in Water ; those on Land are either *roundish in the Body*, with all their Legs rising out of the Middle of the Belly nearly, as the *Tulus* ; or more flat and compressed, with their Legs growing along on each Side, as the *Scolopendra*.

9. And some of these *Multipedes* are *aquatic*, of which Mr. Ray makes three Sorts, *viz.* the *Cornish Lugs* with 38 Feet, the *Scolopendra Marina*, and a *two-tailed Animal* lying in the Clefts of Stones under the Salt Water.

10. The second Kind of Insects are those *which change their Form*, or undergo a real *Metamorphosis*. And this is of three Sorts, or Species, *viz.* The first is when the *Transmutation* or Change is *single and instantaneous* ; there being no sensible Stop or Rest between the Old and the New Form. The second Species is when there is a *double Metamorphosis* ; as first into a *Chrysalis*, and then into a *flying Insect*. The third Species is a simple Change from a Worm to a flying Insect, but yet with a sensible Rest or Stop between one Form and the other.

11. Of the first Species are the *Libellæ* or *Pertæ* produced from an Insect with six Feet ; the *Cimices-Silvestres*, having the Figure of St. Andrew's Cross on their Backs ; the *Locusts* ; the *Gryllo-Talpa*, or *Mole-Cricket* ; *Crickets* of all Kinds ; the *Grasshopper* ; the *Blatta* ; the *Ephemera*, which lives but a Day ; the *Water-Scorpion* ; *Water-Flies* of several Sorts, &c.

12. *Insects* changing Form of the second Species, or which undergo a *double Transmutation*, are very numerous ; they lie a while before their Change quite still, without Food, or changing Place.

13. In respect of their *Wings*, they are either *Vaginipennia*, or such as have *Cases* within which they withdraw and cover their Wings, as all the *Scarabæi*, or *Beetle* Kind ; or *Anelytra*, whose Wings are open and expanded.

14. The *Scarabs*, or *Beetles*, are divided in respect of their Horns into the *Nasicornis*, the *Bucerota*, and *Cervus Volans*, or *Stag-Fly*. In

they are a small, and deemed a despicable Species of Creatures, yet when well considered, and carefully surveyed with a *Microscope*, they will appear the Pride of Nature, wherein she has bestowed more nice and delicate Art, and displayed more profusely the rich Embroidery, and elegant Beauties and Garniture of Colours, than in any of the larger Species of Animals; though unheeded and unseen by us. 2. *Insects* are so called from the Shape of their Bodies, which seem as it were (*insecta*, i. e.) cut into two Parts or Halves, and joined to one another by a small String or Neck, as in *Ants*, *Flies*, &c. 3. They are all *Oviparous*, that is, they lay Eggs, from whence they are all produced. 4. The different Kinds of *Insects* reposit their Eggs in different Places; some in *Beer*, *Vinegar*, &c. some in *Plums*, *Pease*, *Nuts*, &c. as the *Ichneumon Flies*: In *Pears*, *Apples*, &c. as the *Phalænæ* Kind: In the *Bark*,

In respect of their *Antennæ*, they are of many Kinds, of which the most eminent are the *Capricorni*. Some from their Motion are called *Saltatrices*, or Leapers; and others from their Colours are called *Cantharides*.

15. To the Beetle Kind may be referred the *Glow-Worm*; the *Staphylinus*; and the *Oil-Beetle*, so called from its emitting a Sort of Oil from its Joints on being squeezed or pressed.

16. The *Anelytra*, or Insects whose Wings are open, and without Cases, have their Wings either *farinaceous* or *mealy*, as the *Butterfly* Kind; or *membranous* and *transparent*, as the *Fly* Kind.

17. The *Anelytra* with *farinaceous* or *mealy* Wings are of two Sorts, *viz.* *Papiliones*, or *Butterflies*, which fly by *Day*; and the *Phalænæ*, or *Millers*, or *Moths*, which fly by *Night*. The various Sorts of each are so numerous, as scarce to be recounted or methodized.

18. *Anelytra* with *membranous* Wings are a large Species, and comprehends numerous Tribes of the most perfect *Insects*, as the *Hornet*, the *Humble-Bee*, the *Bee*, the *Wasp*, and all the *Fly* and *Gnat* Kind; hitherto is also referred the *Formica*, or *Ant*. Most of this Head come from a *Vermicle* or Maggot by a *Metamorphosis* of the third Kind.

Wood,



*Wood, Buds, Leaves, &c. of Trees.* The *white Butterfly* lays its voracious Offspring on *Cabbage-leaves*: Some, which require Warmth, lay their Eggs about the *Bodies of Animals*, as in the *Feathers of Birds*, the *Hair of Beasts*, and even in the very *Scales of Fish*: Some go farther, and penetrate the Body itself, and its Cavities, and there lay their Eggs, as in the *Nose, Guts, the Kidneys, the Bladder, the Brain*, in the *Gall-bladder* itself, and in the *Flesh* in general. 5. Hence the surprizing Production of *Maggots* and *Vermin* in all those Places, and Parts of *Animals* now mentioned. 6. The *Metamorphosis of Insects* is a Thing extremely astonishing; I shall give from Mr. *Geodart* an Instance thereof: See *Fig. LVII. on Plate XXVI*, fronting p. 342. The *Eruca* or *Caterpillar* A hath its Origin (*saieth he*) from the Egg or Seed of a *Butterfly* C, called the *Peacock's Eye*; I took it the 4th Day of *May* 1635, and nourished it with the Leaves of *Nettles* till the 11th of *June* the same Year; at which Time it began to prepare for its Transformation to the State in which it is called *Chrysalis* or *Aurelia*, as B; in this *aurelian State* it continued changing (with its Head downwards) 19 Days, at the End of which, there proceeded from this *Aurelia* a *Butterfly* C, with four Wings; and from its elegant Colours, called the *Peacock's Eye*, as aforesaid. 7. *Insects* in their first State, as *Maggots* and *Caterpillars*, feed on hard and coarse Diet, as *Leaves, &c.* contrary to other *Animals*; in their *aurelian State*, they subsist without any Food; in their *mature State*, as *Flies*, they live on a more delicate and tender Diet, as *Honey*  
from

from Plants, Blood from Animals, &c. It is discovered by the *Microscope*, that the elegant Colours of *Butterflies*, &c. are owing to neat and well-made Feathers, set with great Curiosity and Exactness in Rows and good Order. 9. The Eyes of *Insects* are hard, fixed, or immoveable; and some have more than two, as *Spiders* have four, six, or eight Eyes: *Flies*, *Wasps*, &c. have the Cornea, or outward Coat of their Eye, made of curious Lattice-work, as is represented magnified in *Fig. LVIII.* on *Plate XXVI.* fronting p. 342. The Eyes of these *Insects* have this Contrivance to supply the Place of the *crystalline* and *vitreous Humours*, which they (it is thought) have not. 10. The *Antennæ*, or *Feelers*, which grow from the Head of *Insects*, serve them to feel out Obstructions and Annoyances in their Walk or Flight; are a good Guard to the Eyes and Head; and in many, a very beautiful Piece of Garniture to the Body. 11. As to the Motion of *Insects*, some creep, some leap, some walk, some swim, and most of them fly; some fly with Wings, others by Help of their Webs, as *Spiders*; and others by Means as yet unknown. 12. The Wings of many *Insects* are a most curious Piece of Workmanship, distended and strengthened with the finest Bones, and these covered with the finest, transparent, and lightest Membranes; some adorned with neat and beautiful Feathers, and many provided with the finest Articulations and Foldings, for the Wings to be withdrawn, and neatly laid up in their *Vaginæ* or *Cases*; and again readily extended for Use. 13. Those *Insects* which have four Wings, have their Bodies thereby kept steady and upright in Flight;

Flight; and those which have but two Wings, have Poises or Pointils, like little Balls, set under their Wings on each Side their Bodies for that Purpose. 14. The Minuteness, Art, and Curiosity of the Joints, Muscles, Tendons, Nerves, &c. necessary to perform the Motion of the Wings, Legs, and other Parts, is a surprising Thing to all who consider it. 15. The *Nidification* of *Insects* far excels the most exquisite human Art, witness the nice geometrical Combs of some, or earthen Cells of others, or the Webs, Nets, and Cases woven by the admirable *Textrine Art* of some others. 16. Again, what strange *Instinct* leads others of those small Creatures to make even Nature itself subservient to their Designs, by making the *Vegetation of Trees and Plants* the Means of building their little *Nests* or *Cells*; such as those Cases, *Galls* and *Balls*, found on the Leaves and Branches of Vegetables of many different Sorts; some being hard Shells, some tender *Balls*, some scaly, some smooth, some hairy, some long, round, conical, &c. 17. They have Parts analogous to the *Brain, Stomach, Entrails, Arteries, Veins, Nerves, Lymphæducts*, &c. yet being so wonderfully fine and tender, are, as it were, included within the hard Case of their outward Body; wherewithal they are cloathed and defended, as with a *Coat of Mail*. 18. Again, how curiously are those outward Teguments, or hard Cases of *Insects* Bodies, contrived? How are they set with *Bristles*, sharp *Spines*, &c. for Defence? How are they adorned with neat Imbrications, and many other Beauties and Fineries? 19. As the Magnitude of some Species of Animals is  
very



very wonderful, on the contrary, the Minuteness of some *Insects* is far more amazing: Mr. *Lewenboeck* has observed more of these *Animalcules* in the Melt of a *Cod-Fish*, at one Time, than there are People living on the Face of all the Earth at once. It is also found, that in a Drop of Pepper-water are contained above 8280000 of those small Creatures; and some are yet discovered smaller than these, so that Millions of Millions might be contained in one Drop of Water. 20. It is the infinite Number of these invifible Animals that makes stagnating Waters appear of so many different Hues, as green, brown, reddish, &c. But I cannot farther enlarge, for want of Time.

A. Well, these Things loudly declare the wondrous Skill and Wisdom of their Maker; and great Pity it is they are not more attended to: But, pray, continue this pleasing Survey next in the Nature of those Creatures you call *Reptiles*\*.

B. In

\* 1. *Reptiles* are either *terrestrial* or *aquatic*. *Terrestrial Reptiles*, or such as are found on Land, or in the Earth; among these the *Serpent Kind* are the principal; of which some are *venomous* in their Bite, as the *Rattle-Snake*, the *Viper* or *Adder*; and, some think, the *Sloe-Worm*; but that, as well as its *Blindness*, is thought by others to be an Error. Some are not *venomous*, as the *common Snake*, and many other Sorts of Snakes in foreign Countries.

2. The next considerable Species of *Reptiles*, are *Snails* of all Sorts: Of these some bear *Shells* of various Forms, Sizes, and beautiful Colours. Others have *no Shells*, as the large *black Snail*, and others of a greenish and yellow Colour; with all that Sort we call *Slugs*, found under Boards on moist Ground, and on the Leaves of Plants, &c.

3. To the Head of *Reptiles* also many refer the *Multipede Kind*; for as they cannot, without great Impropriety, be called *Insects*; and as their Motion, though performed with Legs, is yet a Sort of *Creeping* or *Crawling*, so they may be very fitly called *Reptiles*; but as I have, according to Mr. *Ray's* Method, mentioned them in the last Note as a Species of *Insects*, I shall say nothing more of them here.

4. The

*B.* In the *Reptile Species* several Things are common to other Animals, and have been already observed; and some Things are somewhat parti-

4. The *Lumbrici*, or *Earth-Worms*, are a most conspicuous Part of the *Reptile Kind*: Of these some are of a *larger Sort*, called *Dew Worms*; some of a *lesser Sort*, of these there are *red and green*, with *yellow Tails*; which latter are called *Gilt-Tails*.

5. *Worms* found in the Bodies of Animals make another large Species; as the *Teretes*, the *Lati*, the *Ascarides* in the Bowels of Men; the *Vermiculi Setiformes*, and the *Botti* in the Intestines of Horses and other Beasts.

6. *Aquatic* or *Water-Reptiles* are of various Species; of which, in regard of their Motion, *Eels* make the first Distinction: But, from their more general Nature, they have always been considered among the *Fish Kind*, where of Course I was obliged to take Notice of them in this Survey. See Note, Page 340. Art. 11.

7. The *Leaches* make the next Class of *Water-Reptiles*: Of these there are three Sorts, viz. the *Medicinal Leach*, or *Sanguisuge*; the common black *Horse-Leach*, and the Ash-coloured *Sea-Leaches*. There is also a Sort of this Kind that is *smaller and flatter*, which is found sticking to Stones at the Bottom of Brooks.

8. Besides this, there is another lesser Sort of *Water-Reptiles*, of which some are round, long, and *black*; and others *red*; the Black hath two small Horns on its Head; the Red is about a Finger's Length, with a Forceps at the Tail. To these may be added, those very small and slender *Anguiculæ* which lie in Clusters in stagnant Waters, and from a Vessel of a *red Fluid* which appears through the Body of each, they make the Water look red in divers Places.

9. There is another Sort of this Kind which is *flat*, and very small and thin, and are called *Flukes*; they are sometimes found in Waters, and sometimes in the Branches of the *porus Biliaris* in Sheep. Besides these, there are many other Species without Name or Distinction.

10. I think those *Water-Animals* which are covered with a *Theca*, or Sort of Case, are to be referred to the Class of *Reptiles*. This *Theca* is either *immoveable*, being fixed to the Stones, and is of a Figure round, or else more compressed and flat; or *moveable and portable*; which *Theca* is commonly called *Phryganea*; and is either *straight* or *crooked*.

11. The straight *Theca* is composed either of *Straws* and little *Festucæ*, lying parallel one to another, of which there are two Sorts, a *greater*, where the *Festucæ* are two Inches long; and a *lesser*, which is very common, and are called *Straw-Worms*. Or else the *Festucæ* lie transversely, and are shorter, having sometimes Pieces of *Shells* or *Stones* mixed with them.

12. Others, whose *Theca* or Cases are straight also, have no *Festucæ*, but always either *Sand* or *Gravel*; and of these, some have the *Theca* round, and are called *Cod-baits*; others are flat and compressed.

13. Others

particular and peculiar to them, which I shall remark in the following Order : 1. Their *sinuous, vermicular, or creeping Motion* is very curious, and contrived with the nicest Art, and geometrical Neatness. 2. The whole Body of a Worm is, as it were, but a Chain of *annular or spiral Muscles*, whose orbicular Fibres by contracting render each Ring (at first wide and extended) more straight and long ; and thus the foremost attracting the next behind, the Action is continued through the Length of their Body, and produceth their vermicular or spiral Motion.

3. The *Serpent Kind* move by means of *annular Scales* lying straight across their Bellies, contrary to what they do on the Back, and other Parts of their Bodies. Now the Edges of the foremost Scales lying over the Edges of the hinder from Head to Tail, run out a little beyond them, so that when each Scale is drawn back, or set a little upright by its Muscle, the outer Edge thereof (or Foot) is raised also a little from the Body, to take hold on the Earth, and so producing, by the successive Action of all, the sinuous Motion of the *Serpent*. 4. The *Motion of Snails* is performed by the *undulatory Action* of a long broad Skin along each Side of their Belly ; and they are enabled, partly by a slimy glutinous Matter emitted from their Body, and partly by the Pressure of the *Atmosphere*, to adhere firmly

13. Others have the *Theca crooked or horned*, which runs tapering ; of these there are reckoned four Kinds, a greater and a lesser *black* Sort ; and a greater and lesser *Asb-coloured* one. The *Theca* or Cases of all these Sorts of *Cados-Worms* are admirably contrived, being cemented or glued together in such a Manner, as not to be easily separated one Part from another ; and by that Means these Creatures secure themselves from the Voracity of such Fish as would otherwise make them their Prey.



to all Kinds of Superficies, and in all Postures. 5. *Caterpillars*, while in their *vermicular State*, are curiously provided with little Feet, the foremost short and hooked, to draw Leaves, &c. to them; the hindmost are broad Palms, beset around with small sharp Nails, by which they stick to, and grasp whatever they are upon: Whereas, in their *Nympha* or *Aurelia State*, they have neither Feet nor Motion, but a little in their hinder Parts, and in their *mature* or *insect State*, they have motive Parts proper to that *Species of Animals*. 6. It is a wonderful pretty *Mechanism* observable in the Going of *Millepedes*, (or *Multipedes*) that on each Side of their Bodies every Leg hath its Motion, one very regularly following the other from End to End of the Body; so that their Legs in going make a Kind of *Undulation*, and give the Body a swifter Progression than one would imagine it should have, where so many short Feet are to take so many short Steps. 7. The *Spine* or *Back-bone* of *Serpents* is really wonderful: How thick are they set with Joints, or *Vertebræ*? How numerous and strong are their co-operating small *Muscles*? By what curious *Articulation* of the *Vertebræ* can they turn and wind their Bodies any Way? 8. Some of the *Reptile Kind* are provided with a *poisonous Matter*, serving to the more easy Conquest and sure *Capture* of their Prey; and probably may serve to the Digestion of their Food. 9. The *Poison* of the *Viper* lieth in a *Bag* in the Gums at the End of a certain sharp Tooth, conveyed thither by a Duct from a conglomerate Gland  
lying

lying in the Side of the Fore-part of the Head, by which it is separated from the Blood. This Tooth is *tubulated* or hollow, through which, when the *Serpent* biteth therewith, the Poison is conveyed to the Wound. 10. The *Size*, or rather Length, to which some of these *Serpents* grow, is very surprizing. I have seen the perfect Skin of a *Rattle-snake* 22 Feet long; and there are others from 30 to 40 Feet in Length. 11. Those Creatures of the *Serpentine Kind* are the most *vivacious*, or tenacious of Life, of all other Animals. Thus we see *Eels*, *Adders*, &c. live, have Motion, yea, are very strong, for a great while after they are beheaded, fleaed, and disboweled: The Reason of which is owing to the greater Firmity, Solidity, and Compactness of their Flesh above that of other Creatures; so that the Action of the vital Springs, or Causes of Motion, continue longer in them than in other Creatures. 12. Mr. *Redi* relates, that *Serpents* and *Vipers* will live not only some *Days* or *Weeks*, but *many Months*, without Food, shut up in a Box, yea, that they will be able to *bite*, and emit a *deadly Poison*, after eight, nine, or more months. But if the Vessel be open, and they perspire much, they die, without Food, in a short Time. 13. Some of those *Reptiles*, as *Earth-Worms*, *Snails*, &c. are *Hermaphrodites*; that is, have the *genital* Parts of both Sexes, the same *Worm* being Male and Female, so that they mutually copulate with each other; and the Parts of Generation are placed in the Necks of Snails, just under their Heads. And would you see more of the wonderful Nature, Kinds, and Peculiarities of the

*Reptile Species*, you may be satisfied, by reading the Natural History of the several Parts of *Asia*, *Africa*, and *America*.

*A. Sir*, I thank you; I do not know but that I may, when I have Opportunity and Leisure: But, pray, what have you to observe in the Nature of those you call *Shell-Animals* \*?

*B. My*

\* 1. The Kinds and several *Species* of *Conchilious* or *Shell-Animals* are not well known, nor sufficiently digested by Naturalists; nor is it possible they should, since their *Number* and *Variety* are so exceeding great, and the Bottom of the *Sea* their principal Place of *Habitation*.

2. However, some of the more common and distinguished of this Tribe I shall enumerate and methodize in the following Order. Of *Shell-Fish*, some are *uni-valve*, or have only *one Shell*; others are *bivalve*, or have *two Shells*.

3. Of single *Shell-Fish* there is great *Variety*, both with respect to *Fish* itself, and the *Make* and *Form* of the *Shells*. Some *Fish* having divers and distinct Parts, as *Head*, *Legs*, *Claws*, *Antennæ*, &c. without the *Shell*, as in the *Lobster* and *Crab* Kind. Others are contained entirely within the *Shell*, except when they exert themselves for *Motion*; at least, they have no Parts growing without the *Shell*, as in the *Snail*, *Periwinkle*, &c. Kind.

4. The *Lobster* is the Principal of *Shell-Fish*. His *Habitation* is in *Holes* among the *Rocks*. They have four *Legs* on a *Side*, by Means of which, with their two great *Claws* and broad *Tail*, they move with great *Nimbleness*. It is said, that if one of the large *Claws* be broken off, it will grow again, or be renewed, though no other *Animal* hath the *Power* of renewing a lost *Limb*. Some say, the *Lobster* is *androgynous*, i. e. hath both *Sexes* in itself; but others doubt it. It is reported there are near thirty several Sorts of *Lobsters*, all cloathed with *Shells*; of the *Lobster* Kind are the *Craw-Fish*, the *Prawn*, the *Shrimp*, &c.

5. The *Crab* is the next *Shell-Fish* of Note; its *Legs* and *Claws* are like those of the *Lobster* for *Number*, *Parts* and *Texture*, nearly; but their *Motion* is *latitudinal*, or *side-ways*; their *Eyes* are more prominent than those of *Lobsters*, and therefore want not their *Antennæ*, or long *Feelers*. They live among the *Stones* and *Rocks* like *Lobsters*, and are never found uncovered by the *Waters*, except when very young and small, on the *Shores* at low *Water*. Their *Spawn*, like that of *Lobsters*, consists of small *Eggs*, and the *Time* of *Spawning* in both is the same. The *Crab* Kind hath also its *Species*, as the *Spider-Crab*, the *Soldier-Crab*, &c.

6. The



B. My Survey of them will be very brief; and I shall observe to you, 1. That those Creatures have

6. The *Star-Fish* is another Species of the *Univalves*: They have five pointed *Rays*, which proceed from the Body in the Center, and by bending these backward and forward, move in all Directions indifferently. The Mouths of all this Kind are in the Center of their Bodies, and armed with Teeth; they have several little fleshy Trunks, which they dart into the *Mud*, through which they suck their Food. Their Organs of *Digestion*, *Generation*, or for voiding of *Excrement*, are not yet discovered.

7. The most wonderful Fish of this Kind is the *Stella-Arborefcens*, so called, because from its small Body, as a Center, proceed a prodigious Number of Branches all around, whose numerous and minute Ramifications make a surprizing Kind of *Net-Work*, which the little Animal, floating about in the Water, casts over its Prey, which it then catches as Fish are caught in a *Castling-Net*. There is a Fish of this Sort to be seen in the *Museum* of the Royal Society in *Crane-Court, Fleet-Street*, whose Ramifications are reckoned more than twenty Thousand in Number.

8. Besides these are divers others, whose Natures are very wonderful; as the *Limpets*; the *Venus-Ear*; *Sea-Urchins*, or *Button-Fishes*; *Center-shells*, which are Cells for small Fishes of the *Oyster-Kind*; the *Sea-Horse*; the *Pipe-Worm*; with many others.

9. There are several *Univalve-Shells*, which are wreathed, or of a *spiral* Form. As the *Nautilus*, or *Sailor*; the *Turbinatæ*, or *Whirls* of several Sorts, great and small; the *Sea-Spider*, and *Fingered-Whirl*; the *Mitre*; the *Harp*; the *Top-Whirl*; the *Blackmore-Teeth*; the *Unicorn-Shell*; the *Purple-Shell*; the *Spider-Shell*; the *Buccina*, or *Trumpet*; the great muricated *Whirl*; the *Golden Trochus*; with several others. These Shells are some so large, as to weigh near ten Pounds; and the wonderful Colouring of others surpasses that of Birds, both for the *Variety*, *Order*, and *Intensity* thereof. From that called the *Purpura*, the Ancients extracted their Purple Colour, with which they dyed their Stuffs; though *Cochineal* and *Kermes-Cods* dye a *Scarlet* incomparably better, and more lasting.

10. The second Kind of Shell-Fishes are *bivalvous*, or whose Shells consist of two Pieces, or open with two similar Parts. Among these the *Oyster* obtains the first Place; the *Muscle* next; then the *Scallop*; and, lastly, the *Cockles* of every Kind.

11. These are called *immoveable Shell-Fish*, as not being able to remove themselves from their first Situation; they are also said to be *Hermaphrodite*, as not having the Power to seek at any Distance one of a contrary Sex for Copulation, which therefore is a necessary Provision of Nature.

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have a Sort of middle Nature between Plants and Animals; and therefore the most imperfect of all the animal Creation. 2. They are therefore called *Zoophyta*, from ζῷον, an *Animal*, and φυλόν, a *Plant*; as much as to say, *animal Plants*, or *vegetable Animals*, because they gather Food, and feed with a Mouth like other Animals; but grow or adhere immoveably to a Shell by the Membrane, as Plants grow or adhere to the Earth by their Roots: Such as *Snails*, *Oysters*, *Cockles*, and all the *conchilious Kind*. 3. The *Shells* of these most con-

12. The *Oyster* abides at such a Depth of Waters, as not to be left uncovered by them: But the *Muscle* has generally its Situation in such Places on the Shore or Rocks, as, by the Fall of the Tides, they become exposed to the open Air. The *Cockle* is always bedded in the Sand, upon those Shores which are uncovered at low Tides.

13. The Food of *Oysters* and *Muscles* are some Kinds of *Sea-Weeds*, and the finest Parts of Mud and Sand, and the Wash of the Sea. The *Cockle* seems likewise to draw its Nourishment from Earth, which passes through its Body like *Earth-Worms*.

14. Mr. *Leuwenhoek* says, that *Muscles* lay their Eggs in Strings on the Outside of their Shells, and that these Eggs or *Spawn* continually increase in Strength, till they become perfect *Muscles*; at which Time, Part of the *Egg-shell* is discoverable upon the outward Covering of the Fish, till that Coat is hardened or changed into a firm Shell. *Philos. Trans.* N<sup>o</sup> 336.

15. Mr. *Strachan* tells us, he saw on the Coast of *Ceilan* an *Oyster* of a Foot Diameter; and that the Shell of one of these did grow till it was three Feet in Diameter broad, and a Foot thick, after the Flesh was putrified. *Philos. Trans.* N<sup>o</sup> 282.

16. There are very commonly found *Pearls* of different Sizes in the Bottom of the Shells of *Oysters*, *Scallops*, and especially in that called the *Naker*, or *Mother of Pearl*, where they are generally found in Abundance. The *Pearls* which are sometimes found in the Bodies of those Fishes, seem rather to be *Gravel-Stones* than true *Pearls*, and therefore not so valuable.

17. Besides these Shell-Fish now mentioned, there are many others to be met with in the Works of *Naturalists*, but infinitely more in the Works of *Nature* herself; which must be left to the Search and Industry of future Time, which possibly may arrive by Degrees to a more accurate Knowledge, and give a more perfect History of them, than is now to be had.

temptible

temptible Creatures are yet made with wondrous *Art, Beauty, and Finery* in some particular Species of *Snails, Cockles, &c.* What artful curious Spirals, Circles, and other Divarications and diametrical Divisions, do we observe therein? How are they covered to please the Fancy, and serve the Luxury, even of the human Species?

4. These *Shells, or crusty Houses*, serve the poor soft and boneless Inhabitants for Defence and Security against outward Accidents, from which they can safely retreat therein. 5. A wonderful Thing in *Snails* is, that they have their *Eyes* placed (not in their Heads as other Animals, but) on or at the *Top of their Horns*; which therefore they can move farther or nearer from their Head, and circumvolve them here and there, or one this Way, the other that, at Pleasure. 6.

The *Bodies of Shell-Animals* are contrived without Bones, or any Thing that I know of like them; they consist of a tough membranous Substance, analogous to Flesh and Muscles; and their internal Organs of Life are several, and distinctly appear on being dissected; but what the particular *Shape and Function* of many of them may be, is not so easy to ascertain; the *Bowels and Intestines* of these Creatures bearing but small Analogy to those of more perfect Animals, I shall end my Reflections on them, by giving you a Cut, shewing the mutual Copulation of Snails, by their Genitals G, in *Fig. LIX. on Plate XXVI, fronting p. 342.*

A. It is very wonderful indeed; as are most of the other Particulars which you have related of the divers Species of Animals: But, pray, (before we leave this Survey of the animal Creation)



let me ask your Opinion of *Griffins*, the *Phoenix*, *Dragons*, *Satyrs*, *Syrens*, *Unicorns*, *Mermaids*, *Fairies*, &c. Do you think there really are any such Things in Nature \* ?

B. The

\* 1. It makes but little for the Credit of the Histories of *Dragons*, *Unicorns*, *Mermaids*, &c. that their Names are not to be found in the Transactions of our celebrated Royal Society, who, it is well known, derive their Intelligence at the best Hand from almost all Parts of the World. At least, I can find no Mention of any such Creatures in the seven Volumes of Abridgments by *Lowthorp*, *Eames*, and *Jones*.

2. The *Histoire Naturelle de l'Univers* gives an Account of several Persons who have described the *Unicorn*; and particularly Father *Lobo*, in his Voyage to the *Abyssine Empire*, says, that this Animal is of the Shape and Size of a fine-made and well-proportioned Horse, of a bay Colour, with a black Tail and Extremities; he adds, that the *Unicorns* of *Tuacua* have very short Tails; and those of *Ninina* (a Canton in the same Province) have theirs very long, and their Manes hanging over their Heads. *Vol. IV. Page 3.*

3. *Du Mons* says, he saw the Head of a Dragon which was set up over the *Water-Gate* in the City of *Rhodes*; this Dragon was 33 Feet long, and wasted all the Country round, till it was slain by *Deodate de Gozon*, a Knight of *St. John*. He says, the Head was like that of an Hog, but much larger; its Ears were like a Mule's, but cut off; the *Teeth* were extraordinary sharp and long; the *Throat* wide; its *Eyes* hollow, and burning like two Coals. It had two little Wings on its Back; its *Legs* and *Tail* like those of a Lizard, but strong, and armed with sharp and venomous Talons. His Body was covered with Scales, which was Proof against Arms. See the Manner of his being killed in the *Atlas Geographicus*, *Vol. III. Page 43, 44.*

4. *Ludolphus*, in his *Ethiopic History*, tells us, that in the *Abyssine Empire*, there are voracious scaly Dragons of the largest Size, though not venomous or hurtful otherwise than by the Bite, and they look like the Bark of an old Tree. *Atlas Geographicus*, *Vol. IV. Page 614.*

5. The Stories of *Mermaids*, *Satyrs*, &c. had undoubtedly their Original from such Animals as have in some Respects a Likeness to the human Shape and Features. Among these the *Monkey* Kind, the *Orang Outang*, and the *Quoja Morron*, are the chief on Land; and the Fish called the *Mermaid*, (though it has nothing of the human Form) and some other unusual Animals in the Sea.

6. The

B. The *Phœnix* is mentioned by *Pliny*, and other Ancients, more credulous than skilful; but has long since been rejected as a vulgar Error. The *Griffin* and *Harpy* have had a Place given them in Modern Histories of Nature, but not without great Reproach and Ridicule to the Authors. *Satyrs*, *Syrens*, and *Fairies*, are all Poetical Fictions. The *Scripture* makes Mention of the *Dragon* and the *Unicorn*, and most *Naturalists* have affirmed that there have been such Creatures, and given Descriptions of them; but the Sight of these Creatures, or credible Relations of them, having been so very rare, has occasioned many to believe there never were any such Animals in Nature; at least it has made the History of them very doubtful. As to

6. The Story of the *Quoja Morron* being very uncommon and curious, I shall here insert it from *Dapper*, who says they are found in *Quoja* in *Guinea*, and *Angola* in *Ethiopia*. The *Negroes* call them *Satyrs*, and believe they sprang from the human Race. They have large Heads, thick heavy Bodies, nervous Arms, no Tails, walk sometimes erect, sometimes on all-four; they feed on Fruit and wild Honey; fight continually with one another; they dare attack armed Men, and will sometimes force Women. The *Portuguese* call them *Savages*.

7. *Dapper* tells us, that 30 Years before he wrote, a Female of this Kind was brought to *Holland*, and presented to Prince *Frederick-Henry*. It was as big as a Child of three Years old, but twice as thick, well set, strong and nimble; it lifted Things of great Weight, and carried them from Place to Place. Her Breasts and Belly were naked, but her Back covered with Hair. Her Face was somewhat human, but her Nose flat and turned up. Her Ears, Breast, Nipples, Elbow, Legs, Feet, Belly, and *Pudenda*, were altogether like a Woman's. She often stood and walked upright on her two hind Feet. She would take the Cup in one Hand, support it with the other, and drink very neatly. She also lay down to sleep with her Head on a *Bolster*, and spread the Coverlet over her, as if she had been a human Creature. It is supposed this Species of Creatures first gave Rise to the poetical Kind of *Satyrs*. See *Atlas Geogr.* Vol. IV. Page 376, and 561.

*Mermen* and *Mermaids*, there certainly are such Creatures in the Seas as have some distant Resemblance of some Parts of the *human Shape, Mien,* and *Members*; but not so perfectly like them, it is very probable, as has been represented. In all such ambiguous Pieces of History, it is better not to be positive, and sometimes to suspend our Belief, rather than credulously embrace every current Report, or vulgar Assertion, which may perhaps expose us to Ridicule, but can't procure us any solid Reputation for Wisdom and Learning.

*A.* Well, leaving these uncertain Subjects, let us conclude this short View of the Creation with what you called the *Accidents* of animal Life; pray what do you reckon such?

*B.* They are such as follow, *viz.*

*Health*: This ariseth from an apt Construction and due Temperament of the Parts, whereby they are capable of performing all the natural Actions and Functions of Life.

*Disease*: This is that State of an animal Body, which deprives it of the Faculty of exerting every Action proper for it.

*Vigilance*, or the *State of being awake*: This ariseth from the Presence and Action of a due Quantity of animal Spirits through all the Parts of the Body; by Means of which the Organs of the external and internal Senses, and all the Instruments of Motion depending on the Will, are properly affected by external Objects, and easily perform all their Actions and Motions.

*Sleep*: The State contrary to *Vigilance*; but what is the Cause, or wherein it doth consist, the greatest



*Of Dreams, Hunger, Thirst, and Death.* 361

greatest *Physiologists* differ in their Determinations, and are puzzled to account for it.

*Dream* : This is an Action of the *reflective Faculty* of the Mind, which is always active even in Sleep, and doth therein recollect and review the *Ideas* which were present to it when the Body was waking : But the Body asleep not admitting the Exercise of the *rational Faculty* of the Mind, it rangeth those *Ideas* for the most Part in a confused, unnatural, and imperfect Manner ; and this Vision of Things we call a *Dream*.

*Hunger* : This is that Quality which ariseth from a *Vellication* of the inner Coats of the Stomach, by the Action of the digesting Juice ; which, having no Food whereon to spend its Force, gnaws on the Stomach itself, and thereby excites in our Minds the *Desire*, or *Appetite of Food*.

*Thirst* : This is somewhat analogous to *Hunger* ; for a due Quantity of Moisture being wanting in the Stomach, and Parts of the Throat and Mouth, produceth that *molesting Sensation*, which creates in us a *Necessity of drinking*, to remove it.

*Death* : This brings an Animal to its last State ; and is nothing but a final Obstruction or natural Cessation of all the animal and vital Faculties and Functions of the Body ; which then remains in a State of perfect Quiescence, and is entirely passive to all other Changes and Conditions it meets withal in this World. And, as *Death puts an End to all Things*, so I judge it most natural to end this long Reflection on the  
wonderful

wonderful Works of God, the great Author of Nature, with the *awful Subject of Death*; which also, ere long, will intercept all such delightful and agreeable Converſe, as hath hitherto paſſed between you and me.

*A.* Ah! Were it not for the Proſpect of a better, and a more perfect State of Life and Being hereafter, how dreadful would be the Thought of parting with our *dear, our friendly and agreeable Company* and Acquaintance, even in this Life of Troubles! I am heartily ſorry that our Knowledge extends no farther in the Nature of Things; ſince it is a Topic, which, of all others, gives me the moſt ſerious and perfect Pleaſure in the Contemplation of it. And, ſince you have taken abundant Pains to replenish my Mind with the beſt Treafure of this Sort of Science, I can but love you, and return you my ample Thanks for the ſame.



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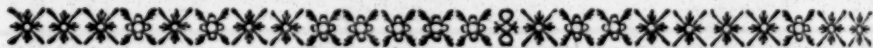
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